HUMAN FALL DETECTION WITH MONITORING AND DATABASE SYSTEM

by

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Bachelor of Science in Computer Engineering

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Approval Sheet

Mapua Institute of Technology

School of EECE

This is to certify that I have supervised the preparation of and read the design report prepared by **Dominic P. Camba, John Lester S. Magno, Jerome M. Torregoza and Gizelle Ann C. Tuason** entitled **"Human Fall Detection with Monitoring and Database System"** and that the said report has been submitted for final examination by the Oral Examination Committee.

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ROLES AND RESPONIBILITIES OF GROUP MEMBERS

Name	Tasks
Camba, Dominic Richard P.	• Debugging of C# Program and Arduino Board Program • Buying of Materials • Mounting and soldering of components on PCB • Compilation & Finalization of Documentation
Magno, John Lester S.	• Part of Chapter 1 of Documentation • Part of Chapter 3 of Documentation • Testing of Prototype for Chapter 4 of Documentation • Chapter 5 of Documentation • Arduino Board Program
Torregoza, Jerome M.	• Part of Chapter 1 of Documentation • Part of Chapter 2 of Documentation • Contacting of the Target Customer • Circuit Design
Tuason, Gizelle Ann C.	• Part of Chapter 1 of Documentation • Part of Chapter 2 of Documentation • Part of Chapter 3 of Documentation • Summarizing of Data for Chapter 4 of Documentation • C# Program and Database

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ABSTRACT

The continuous development of fall detection devices serves a great impact not only to the patients but also to the nursing staffs who observe the current standing of the patients. Unlike the existing fall detection devices, the monitoring ratio of the devices one-is-to-one; meaning only one (1) fall sensor device can send a signal to one (1) monitoring device. In addition, if an incident happens, no records are kept at all. This paper presents the research and development of the existing fall detection devices using three-axis accelerometer, PIC Microcontroller, ZigBee transmitter and receiver, and Arduino Board. The PIC Microcontroller in the monitoring device was programmed in such a way that multiple fall sensor devices signals can be interpreted. The Arduino Board serves as a bridge from the monitoring device to the computer, so that if an incident happens, the signal from the monitoring device will pass through the Arduino Board, and the signal will be interpreted by a Monitoring Device Application Software (MDAS). The MDAS can record the patient's name, ID, room number, time and date of the incident into a database. After the research and development of the previous systems and the data gathered from the testing, it is concluded that the device can support two or more sensor devices which may lessen the cost of a fall detection system. The devices have also provided a 100% of detection for fall incidents. The Monitoring Device Application Software has provided notification for the monitoring device and the incidents were recorded into the database of the program.

Keywords: Three-axis accelerometer, Microcontroller, ZigBee, Fall Detection, Database

Chapter 1

DESIGN BACKGROUND AND INTRODUCTION

This chapter presents a general overview of the design entitled, "Human Fall Detection with Monitoring and Database System". It includes a discussion about the organization which needs a solution to a certain problem, and about the problem that is aims to be solved. This chapter also provides the solution to the problem and the objectives proposed to the organization, as well as its impact and benefits in terms of different factors. The proposed solution is also distinguished from the existing systems in this chapter.

Customer

The target customer in this design project will provide a solution to the problem, Lubang District Hospital. It is a small government hospital situated at Baranggay Tangal, Lubang, Occidental Mindoro. The vicinity can be reached either by air or sea transportation from Manila or Batangas province, respectively then a short tricycle ride to Barangay Tangal. It is classified as a Level 1 category district hospital with a 25-bed capacity. The few patients go in due to active centers nearby. The severity of the cases that are taken care of the hospital is low. Cases with higher severity and need immediate attention are taken through a plane in a small port nearby because the hospital cannot handle such cases due to lack of modern medical instruments. One nurse, one mid-wife per shift

are on job rotation, and the doctor works 24 hours. Most of the patients are elderly and need attention as well as assistance for their treatment.

Need

Health-related issues are critical for both the patient's relatives and health personnel; one of those issues are human accident falls. Human accident falls can be characterized into four (4) risk factors. These four (4) risk factors are the following: (a) Intrinsic – caused by age, low mobility, diseases like Parkinson and Chronic, low or poor lifestyle, and sight problems like Vertigo, (b) Extrinsic – caused by drug cocktail, (c) Internal Environment – caused by going up and down the stairs, slippery floors, and (d) External Environment – caused by damaged roads, crowded places, poor lighting. These are the factors mostly cause accidental fall incidents. Those who experience unsupervised fall incident may suffer psychological effects (fear, anxiety, or depression), physical effects (injury, fractures, or sometimes even death), and economic effects (fees for medical examinations, hospital equipments). But the problem with the hospital is it does not have a low-cost system which can effectively monitor fall incidents.

One reason why people are admitted to hospitals is they want to be checked-up and/or be cured, which needs to be monitored by the doctors, nurses, and specialists of their conditions. Monitoring in some public hospitals like Lubang District Hospital is not at all integrated, unlike in private hospitals where the monitoring devices are expensive (video and audio monitoring). Also,

the number of hospital personnel is very limited to check on over all the patients at the same time. So, the customer wants to implement a new system wherein an automatic alarm, specifically for fall incidents can be set and determined where the patient's room is. Further, the customer needs records of fall incidents so that they can track the patient's condition to apply appropriate medical treatments.

Solution

For a small hospital like this, an inexpensive and reliable fall detection with monitoring and database system must be implemented. The whole system is composed of several fall detecting devices which will be worn by the patients who are experiencing immobility or other factors that can cause a fall accident, a single monitoring device with database where the fall incidents are recorded, and an alarm is triggered whenever a patient experiences a fall. The fall detecting devices use a wireless transmitter to send the signals to the monitoring device, and an accelerometer to detect the change in orientation of the patient. The monitoring device with alarm is connected to a computer to sync the data entering the monitoring device with a program to notify the personnel and to record the information regarding a certain fall incident. The sensor devices can simultaneously send signals to the monitoring device where the buzzer alarm will be triggered, and the computer software will indicate the names and the rooms of the respective patients which are in need of assistance.

Objectives

The objectives of the design project as a solution proposed to the customer are as follows:

1. To create a low cost monitoring device that can support two (2) or more fall detection devices that will use accelerometer and a microcontroller to sense the orientation of the patient, and ZigBee technology for the wireless transmission of the signals.
2. To develop a software that will read the signals from the monitoring device and display the patient's name, room number, and time of event.
3. To deploy a database system that will store the information from the Monitoring Device Application Software (MDAS) for further medical use.

Constraints

The distance of the wireless technology used in transmitting the signals from the sensor device to the monitoring device is limited. Any range farther than the standard can cause an interruption in the system. The sensor device must only be worn anywhere along the trunk of the person. It is set to distinguish a fall from a non-fall based on the center of gravity of the body. But since some activities have drastic changes in acceleration even if it is a non-fall, a false alarm button will be set.

The monitoring or receiving device can still generate an alarm even if it is not connected to the Arduino Board or if the software is not available, but the

information regarding the patient who has triggered the alarm will not be displayed and the incident will not be recorded.

Impact

The health and safety of the patients are very much considered because having a monitoring device will help in the reduction of psychological and physical effects concerning the risks of unsupervised fall incidents, as discussed in the first part of this chapter. The system's social impact extends to its flexibility such that it cannot only be used for hospitals, but it is also essential for home use. And since the fall detecting device is also flexible to different kinds of person, there is no need to buy a particular device for a certain type of person. It can be used by children, elderly, and persons with disability. This relates to meeting the economic needs of the hospital. Given that the single monitoring device can accommodate several fall detecting device, the cost of the whole system will be lessened.

Differentiation

In the past, various solutions have been proposed to detect fall incidents. One solution is to have the person raise alarm by pushing a button from a wearable device when they meet an accident. When triggered, it notifies the hospital through an alarm so that the hospital personnel can provide medical precautions or actions to the accident. But the problem with this solution is it depends on the person's capability to push the button, and the solution will be useless if the person become unconscious after the fall since there is a possibility

of a head injury. Another solution is the video and audio monitoring wherein cameras, speakers, and microphones are setup in a room to observe the person, but these solutions are limited to fixed area and fixed equipments. In addition, privacy issues are considered which means observers or hospital personnel cannot monitor the person all day. In recent research, the fall detection is integrated with a wristwatch wherein it uses accelerometer sensors. The concept is to calibrate first the accelerometer sensors by slowly rotating the device in order to project the gravity vector on the three axes in various configurations. The resulting acceleration signals roughly define the surface of a sphere in a three dimensional space and having a reference acceleration on the three axes. Then the device will be worn on the person's wrist for observations. When worn, if a fall happens, there is a sudden change in acceleration on the three axes giving a signal, which transmits through wireless network via Bluetooth, to a guardian or hospital personnel that a fall happened.

In some cases (fall from a chair), a fall may occur without moving the arms drastically, causing change in acceleration. Given these situations, the setback of the recent device, since it is placed on the wrist, is it will only be effective for detecting falls from a much higher space (i.e. 3-4 feet higher), because the whole body must experience the fall for the accelerometer to detect sudden change in acceleration. Also, the arms are very prone to unnecessary movement, such as swaying which may also cause sudden change in acceleration even if the body is not experiencing a fall.

Most rooms for patients in hospitals and clinics are installed with phones direct to the nurse station or wards so that when the patients need assistance or for emergencies reasons, they can immediately call the attention of the nurses or hospital personnel. The problem with this kind of system is when a fall incident happens there is a possibility that the patient can be injured or fractured; or be unconscious, which means they are not capable to call for assistance. Also, with all of these existing solutions for fall detection and monitoring, the ratio of the sensor device to the monitoring device is one-is-to-one. This means that for every patient, different set of systems will be needed. This will not be practical for the hospital since the budget is considered.

Benefits

The system is beneficial to the hospital because it costs cheaper due to the many-to-one ratio of the fall detecting device to the monitoring device. And since a database is provided, the monitoring device can easily determine who among the persons wearing the fall detecting device has experienced a fall. The device can help guardians and/or hospital personnel on how they will be informed about the situation of the patient to immediately attend to any fall incidents and lessen the damages caused by accident. It may also help the casualty to prevent/remove after-effects physically (such as injury, fractures, etc.), psychologically (such as fear, anxiety or depression), and economically (unwanted and high cost medical fees).

Definition of Terms

1. **Accelerometer.** An electromechanical device that will measure acceleration forces. These forces may be static, like the constant force of gravity pulling at your feet, or they could be dynamic - caused by moving or vibrating the accelerometer. (Dimension Engineering, 2012)
2. **Microcontroller.** A single chip that contains the processor (the CPU), non-volatile memory for the program (ROM or flash), volatile memory for input and output (RAM), a clock and an I/O control unit. (PC Magazine, 2012)
3. **Database.** A data structure that stores organized information. (TechTerms Inc., 2012)
4. **ZigBee.** A wireless technology developed as an open global standard to address the unique needs of low-cost, low-power wireless M2M networks. (Digi International Inc., 2012)
5. **Arduino.** An open-source electronics prototyping platform based on flexible, easy-to-use hardware and software.

Chapter 2

REVIEW OF RELATED DESIGN LITERATURES AND STUDIES

This chapter provides a short overview about a fall detecting device and its application as a health care system. The researchers have gathered the following previous studies, articles, and journals which are related to the design project entitled, "Human Fall Detection With Monitoring And Database System." The collection of citations will be used as a reference in developing the proposed system.

Accidental Fall Incidents

A fall can be defined as unintentionally coming to the ground or some lower level and other than as a consequence of sustaining a violent blow, loss of consciousness, sudden onset of paralysis as in stroke or an epileptic seizure (Gibson et al., 1987). For those who live at home, almost half of the falls take place near or inside the house (Campbell et al., 1990; Lipsitz et al., 1991). According to Hammadi Nait-Charif and Stephen McKenna in their study "Activity Summarisation and Fall Detection in a Supportive Home Environment" (2004), home environments are able to monitor automatically the activities of their occupants can help extend independent, quality living, and reduce healthcare costs. Majority of people who experience accidental falls are children, the elderly, and persons with disability due to the reduction in their mobility.

Ge Wu and Shuwan Xue wrote the article "Portable Preimpact Fall Detector With Inertial Sensors" (2008) mentioned that hip fractures are the most common fall-related problem. Wu et al. (2008) cited that falls may occur in many ways such as backward falls, forward falls, sideway falls, and straight-down falls (Smeesters et al., 2001). The author of the publication "Reduce Accidental Falls in Your Home", Claudia C. Collins, stated that between 30-60% of adults over age 65 fall each year. And, of the more than 200,000 elders who experience hip fractures each year, nearly one third result in death, less than a half return to full function, and 30% of survivors require long-term care (Collins). Moreover, in a study entitled "A Study on Detection of Risk Factors of a Toddler's Fall Injuries Using Visual Dynamic Motion Cues" (2009), the author Hana Na avowed that young children are not able to assess risks for themselves. They also have poor coordination and balance and need to touch and explore to learn about the world around them. These factors all mean that children are particularly vulnerable to accidents (Na, 2009). Although the other consequences of accidental falls may be minimal such as scratches and bruises, it is still a high risk for people who stay in a room alone or those who has mobility incapability.

In a survey conducted by Abbate, Avvenuti, Corsini, Vecchio, and Light, entitled "Monitoring of human movements for fall detection and activities recognition in elderly care using wireless sensor network",stated that accidental falls among elderly people are the main cause of admission and extended period of stay in a hospital. Statistics revealed that it is the sixth cause of death for

people age 65, the second for people between 65 and 75, and the first for people over 75 (Bradley et al., 2009). The survey also showed that among the people affected by Alzheimer's disease, the possibility of a fall is increased by a factor of three.

Na stated in her study that on the average, over two million children per year in the United Kingdom are taken to the hospital after having an accident, and approximately two hundred children per day are hospitalized and one child dies as a result of unintentional injuries in Australia. Most of the fall incidents take place at home where children below five years old are the most vulnerable to injuries because this is where they spend most of their time. Falls account for over 40 per cent of all home accidental injuries on children (Na, 2009).

Fall Detection Approaches and Applications

There are different approaches to monitor a certain patient with regard to fall incident. Push buttons can be used as a trigger to alarm the guardian; the implementation of audio and visual monitoring; and embedding motion sensors like accelerometers on a wristwatch and detecting a certain fall incident. But these approaches have unique disadvantages: (1) when an incident happens, if the patient becomes unconscious, he/she is not capable to trigger an alarm using a push button; (2) privacy issues and high-cost implementation for the audio-visual monitoring; and (3) using wristwatch is prone to a drastic change in acceleration, like swaying of arms, that can lead to a false alarm.

Because of these incidents and the threat for people's safety, certain techniques and technologies have been developed to improve the monitoring of the patients' activities. Tong Zhang, Jue Wang, Liang Xu, and Ping Liu mentioned in their study entitled "Fall Detection by Wearable Sensors and One-Class SVM Algorithm" (2006), said that the early detection of a fall is very important to rescue the subjects and avoid the badly prognosis. This makes the development of this type of technology to be important to assist and to protect people experiencing difficulty in balance.

In the study conducted by Abbate et al., cited related surveys of research on patient monitoring technologies. In their citation, Noury et al. (2007) described a system, algorithm, and sensors used for fall detection of elderly people. They discovered the lack of common framework and proposed some performance evaluation parameters in order to compare different systems (Abbate et al.). Another was Yu (2008), who focused on a classification of the approaches and principles of existing fall detection methods. He provided a classification of falls and a general framework of fall detection, alert device, and system scheme.

In the research work "Fall Detection and Activity Recognition with Machine Learning" written by Lustrek et al. (2009), he enumerated four types of approaches to fall detection – (a) the first approach is by the use of accelerometers, typically three-axis accelerometers, which is a device for detecting magnitude and direction of acceleration caused by the pull of gravity

along a single axis; (b) the second approach uses gyroscopes, where the object is equipped with gyroscopes along with three axes and detects the object's orientation and change in orientation, from which the angular velocity is computed; (c) the third is denoted visual detection without posture reconstruction which is based on extracting input data from still images or video; and (d) the last is visual detection with posture reconstruction which is based on 3D locations of markers placed on an object or the human body.

Latest technologies today include handheld devices or wearable devices which send signals into a certain system or station to indicate that an accidental fall has occurred. Zhang et al. (2006) described these wearable sensors as a means of embedding micro sensors into clothes, girdle, etc., to monitor the movement parameters of human body in real-time, and determine whether there is a fall that occurred based on the analysis about the parameters. But the authors said that there exist many problems about this kind of algorithms; include lacking of adaptability, deficiently in classification precision, etc.

As mentioned in one of the approaches, the study will focus on the use of three-axis accelerometers to detect fall detection and the device will be embedded with a ZigBee wireless transmitter to forward data to a remote system which will manage the monitoring of the patient. Since the different kinds of fall, as mentioned earlier in this chapter, have their own distinct characteristics, the flexibility of the detecting device must be considered in order to develop a fully efficient and effective system. To solve the dilemma of adaptability, the

researchers proposed a clipped-style sensor to be placed near the belly of the user. According to the study carried out by Wu et al. (2008), they have stated it was hypothesized that a single sensor with the appropriate kinematics measurements and detection algorithms, located near the body's center of gravity, would be able to distinguish an in-progress and unrecoverable fall from non-falling activities. Thus, the effectiveness of the signals which will be sent to the remote system would be most likely higher, compared to the detection of a device which is worn on the wrist or used a device used as a pendant. These positions of the devices are inclined to the detection of sudden change in acceleration due to involuntary or spontaneous movements such as swaying or other movements which require the use of the arm; and may trigger the sending of data into the remote system even if it is not an actual fall which requires attention.

Accelerometers

Dimension Engineering, a manufacturer of electronic and electro-mechanical parts, has published "A beginner's guide to accelerometers" where they described an accelerometer as a device which measures acceleration forces. They said that by measuring the amount of static acceleration due to gravity, the angle at which the device is titled with respect to the earth may be computed. From a product description of Modern Device, they stated that by sensing the amount of dynamic acceleration, the accelerometer can measure how fast and in

what direction the device is moving. By these two properties of an accelerometer, it may be used together with other algorithms to detect human fall instances.

Another guide published by Parallax Inc. (2005), it was mentioned that the use of an accelerometer can be very useful for various applications such as self-balancing robots, tilt-mode game controllers, car alarm systems, crash detection, leveling tool, human monitoring, etc.

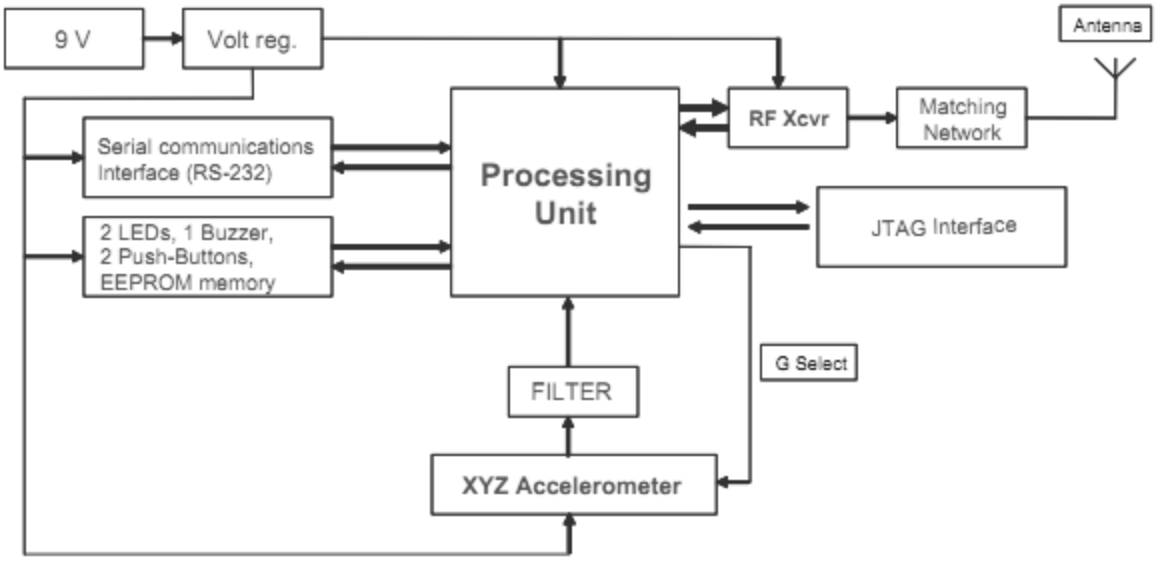

Figure 2.1 Human fall detection block diagram, *Source: Reyna et al., 2005*

Freescale Semiconductor Inc. has issued a reference manual entitled "Human Fall Detection Using Three-Axis Accelerometer" in 2005, developed by Rogelio Reyna, Edgard Palomera, Rogelio Gonzalez, Sergio Garcia de Alba, and Michelle Clifford. The document contains information about the application of the three-axis low g accelerometers (MMA7260Q), 2.4 GHz RF transceiver data

modem for 802.15.4 applications (MC13192), and the Digital Signal Controllers from Freescale (MC56F8013). As illustrated in Figure 2.1 is the block diagram of the hardware module. This can be used as a reference for the implementation of the device proposed in this thesis.

Threshold-based tri-axial accelerometer

The study by Bourke, O'Brien, and Lyons (2006) entitled "Evaluation of a threshold-based tri-axial accelerometer fall detection algorithm" described the development and testing of a threshold-based algorithm which can determine an actual fall event from a usual daily activity, using tri-axial accelerometers. The accelerometers which they will place on the trunk and thigh will have peak values during a fall, which will be distinct from the signals produced during the performance of a normal activity (Bourke et al., 2006).

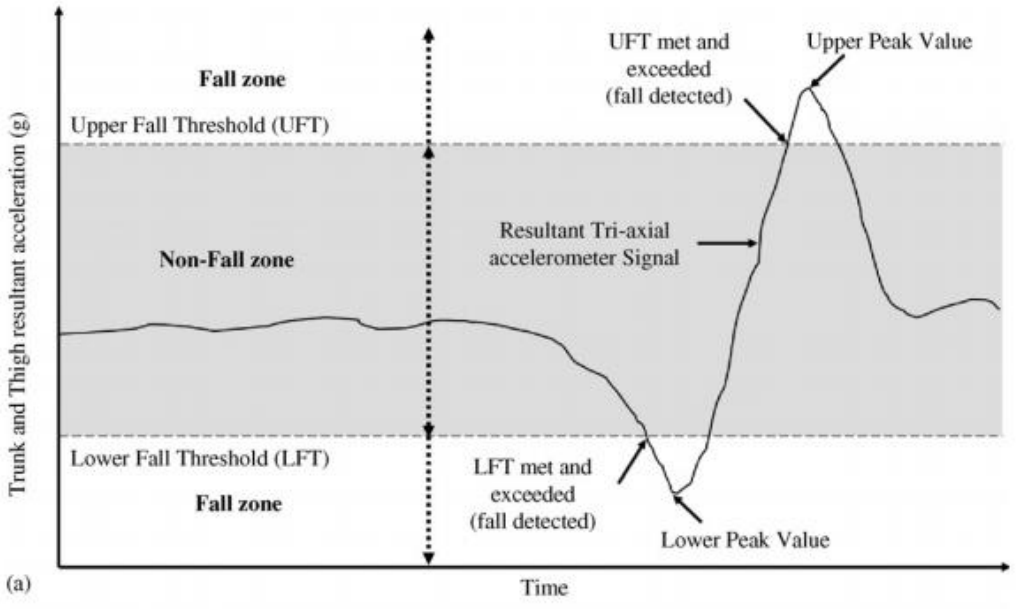

Figure 2.2.1 Trunk and thigh resultant signals, *Source: Bourke et al., 2006*

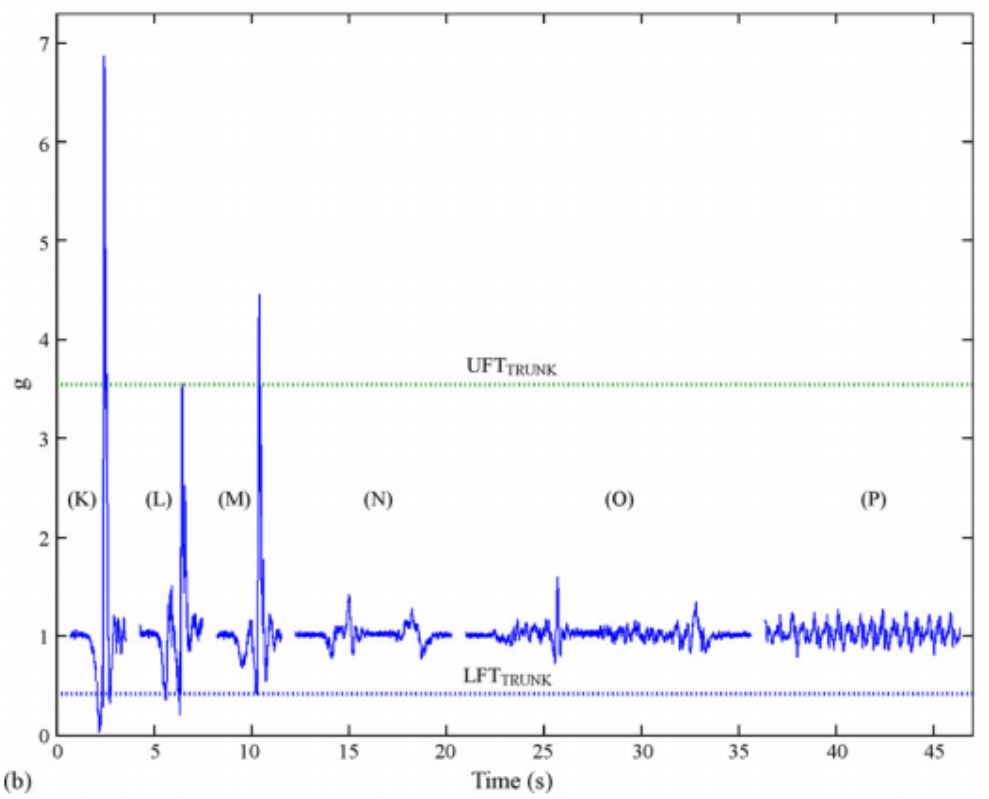

Figure 2.2.2 Typical fall and normal activity signals, *Source: Bourke et al., 2006*

According to the study, the resultant signal from both the tri-axial accelerometer sensors at the trunk and the thigh were derived by taking the root-sum-of-squares of the three signals from each tri-axial accelerometer recording. They had defined four threshold values: upper and lower fall thresholds for both the trunk, and the thigh. As an algorithm example, they have used artificial sample signals in Figure 2.2.1: trunk and thigh resultant vector signals; and in Figure 2.2.2: a typical fall (K), a fall that produced the smallest upper peak value (L), a fall the produced the smallest power peak value (M), a typical sitting on an armchair activity (N), getting in and out of a car seat activity (O), and walking (P).

The authors also stated that the type of sensor used in their study could be woven into a tightly fitting garment and the tri-axial accelerometer could be mounted onto a flexible PCB with a wireless connection to monitoring electronics. As their suggestions for further developments, the device could be incorporated into a portable unit, capable of both fall detection as well as mobility monitoring upon detection of a fall, an emergency message could be sent through GSM model in form of SMS. In the researches' study, the device for the detection of a fall will be incorporated into a portable unit, but is restricted to SMS alert. Instead, the researchers have proposed a wireless transmission into a remote system or unit to alert or to notify that a fall occurrence.

MEMS accelerometer technology

A field applications engineer of Analog Devices Inc., Ning Jia wrote the article "Human Fall Detection Using New MEMS Accelerometer Technology" (2009), where he discussed the technological advances in micro-electromechanical system (MEMS) acceleration sensors have made it possible to design fall detectors based on a three-axis integrated MEMS accelerometer. In his study, the fall detector is mounted to a belt on the individual's body while performing different types of activities. The changes in acceleration while (a) walking downstairs, (b) walking upstairs, (c) sitting down, and (d) standing up from a chair are illustrated in Figure 2.3.1.

He said that since the movement of elderly people is slow, the acceleration change will not be drastic during walking motions. But the accelerations during a fall change notably. In Figure 2.3.2, the acceleration change during an accidental fall is shown. The four critical differences characteristics of a falling event can be used as criteria for fall detection (Jia, 2009).

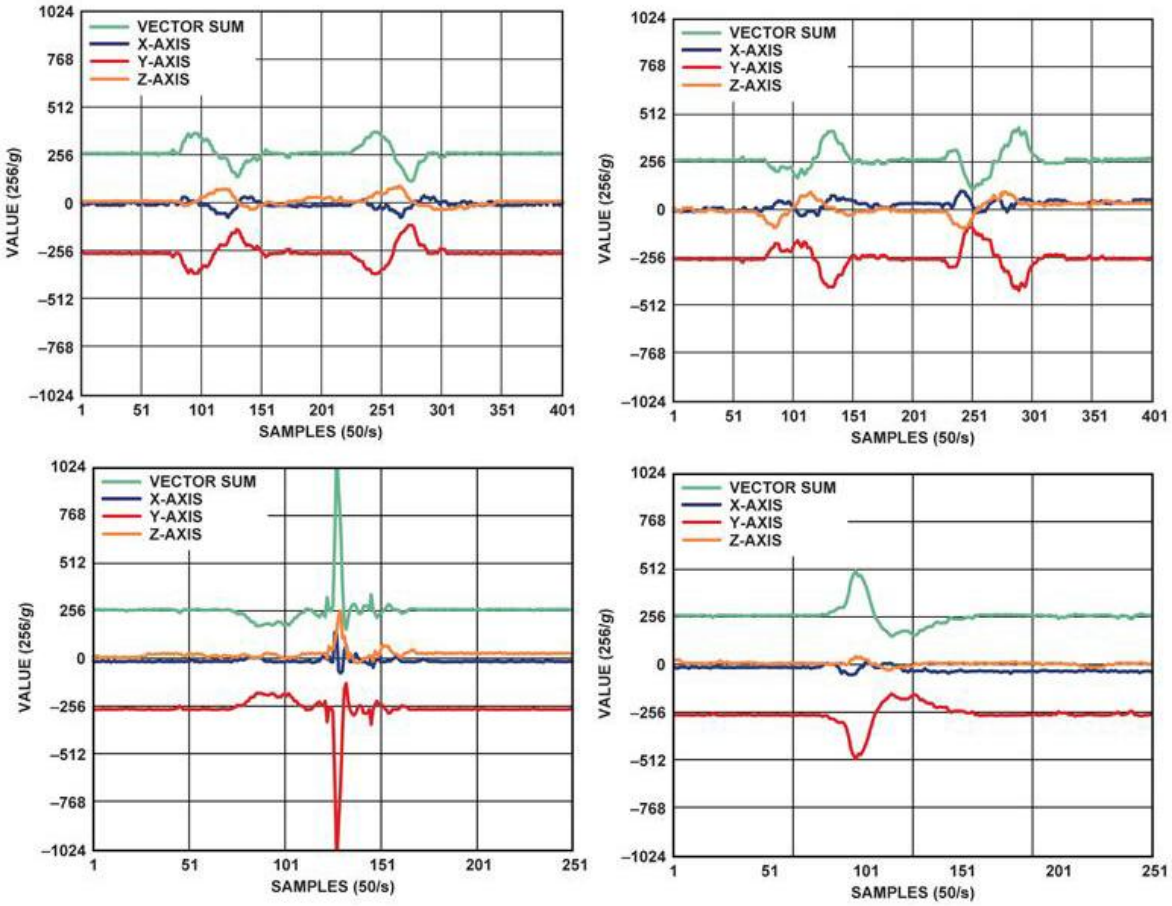

Figure 2.3.1 Accelerometer responses to different types of motion, *Source: Jia, 2009*

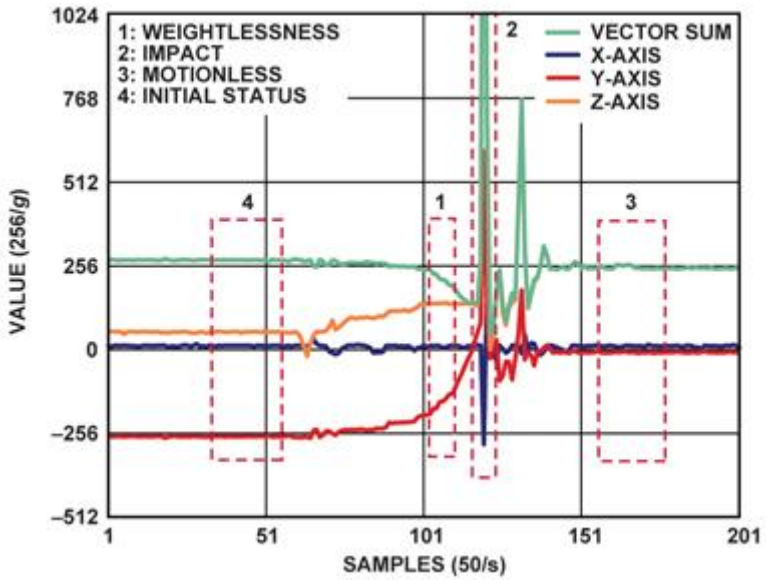

Figure 2.3.2 Acceleration change during an accidental fall, *Source: Jia, 2009*

.NET Framework

The .Net framework is a windows component that allows users to build, execute and deploy .net applications and XML services. The .Net Framework is designed to provide consistency in programming whether it is stored or executed locally or internet-distributed or externally executed or remotely. It also provides code-execution environment to avoid software deployment and version conflicts, promotes safe execution of code either by external or third party codes, and eliminates performance problems of scripted environments. Furthermore, the .Net Framework makes the developer experience consistency among diverse types of application such as window based or web based applications. It also ensures that the code based on .net framework will be able to be integrated with any other code.

The .NET Framework has two main components: the common language runtime and the .NET Framework class library. The common language runtime is the foundation of the .NET Framework. The runtime acts as an agent that manages code at execution time, providing core services such as memory management, thread management, and remoting, while also enforcing strict type safety and other forms of code accuracy that promote security and robustness, the concept of code management is a fundamental principle of the runtime. Managed code is a type of code that targets the runtime or the codes in runtime, while the unmanaged code does not. In .Net Framework Technology, there is a so-called "class library" which contains an object-oriented collection of reusable type that can be used to develop applications from CLI or Command-Line Interface, GUI or Graphical User Interface to the latest innovations provided by the framework such as web forms and XML services.

ZigBee Technology

ZigBee is the set of specifications built around the IEEE 802.15.4 wireless protocol. The IEEE is the Institute of Electrical and Electronics Engineers, a non-profit organization dedicated to burden technology involving electronics and electronic devices. The 802 group is the section of the IEEE involved in network operations and technologies, including mid-sized networks and local networks. Group 15 deals specifically with wireless networking technologies, and includes the now ubiquitous 802.15.1 working group, which is also known as Bluetooth®.

The standard itself is regulated by a group known as the ZigBee Alliance, with over 150 members worldwide. ZigBee devices are actively limited to a through-rate of 250 Kbps, compared to Bluetooth's much larger pipeline of 1Mbps, operating on the 2.4 GHz ISM band, which is available throughout most of the world. (Brendan McGuigan, 2012)

According to Gary Legg, technologists have never had trouble coming up with potential applications for wireless sensors. This is due to Wireless sensors are easier to install than wired sensors. Even for large industry environments, large amount of cost is spent for hard wired sensors. Then there comes the wireless sensors, where wiring is not practical or applicable. The problem now is that the wireless sensors uses too much power, therefore their power supplies must be large enough but not the batteries to be replaced often. Moreover, some doubt the reliability of the sensor data that is sent across the air.

Most of the time, a ZigBee node is at sleep-mode for saving power, if necessary, it triggers to active-mode then sends the data and then goes back to sleep-mode again. And, because ZigBee can transition from sleep mode to active mode in 15 msec or less, even a sleeping node can achieve suitably low latency. Someone flipping a ZigBee-enabled wireless light switch, for example, will not be aware of a wake-up delay before the light turns on.

Another factor for conservation of power comes from the radio technology of 802.15.4. It uses Direct-Sequence Spread Spectrum technology (DSSS) which

accounts for direct transfer of data unlike in FHSS or frequency-hopping spread spectrum that needs more power in keeping its frequency hops synchronized.

To save as much power as possible, ZigBee employs a talk-when-ready communication strategy, simply sending data when it has data ready to send and then waiting for an automatic acknowledgement. According to Bob Heile, who is chairman of both the ZigBee Alliance and IEEE 802.15, talk-when-ready is an "in-your-face" scheme, but one that is very power efficient. "We did an extensive analysis that led to the best power-saving strategy on various kinds of environments from quiet to noisy," Heile says. "We discovered that, hands down, we were better off just sending the packet and acknowledging it. If you don't get an ack, it just means you got clobbered, so send it again. You wind up having much better power management than if you listen and determine if it's quiet before you talk." (Gary Legg, 2004)

Chapter 3

DESIGN PROCEDURES

This chapter gives the discussion about the procedures and methods used in designing and developing the proposed system of the design project entitled, "Human Fall Detection with Monitoring and Database System." The procedures concerning the hardware, software, and prototype development of the system are specifically described in this chapter. The hardware development discusses the system in terms of block and schematic diagrams, as well as the functions of each part. The software development is explained through program flowcharts, and the prototype development gives the details about the materials and components used in assembling the prototype.

Hardware Development

The researchers have gathered information about the assembly of the previous systems, such as circuit designs and the components used. These were used as basis in designing the hardware part of the system. The components used in the proposed system were thoroughly researched to come up with a cost effective and more convenient fall detection and monitoring device. After collecting the information, the components were chosen and the working circuits were designed. These were simulated through certain software and the prototype was constructed.

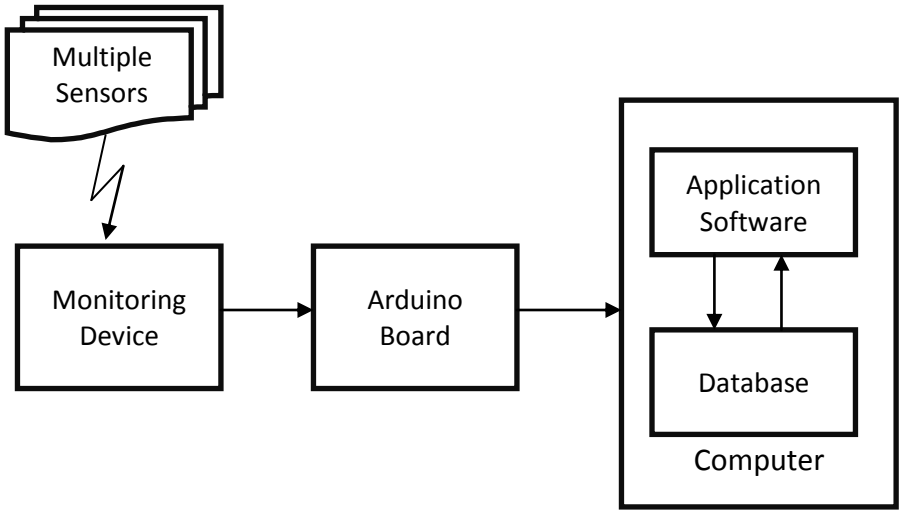

Figure 3.1 Block diagram of Fall Detection with Monitoring and Database System

Figure 3.1 illustrates the block diagram of the system. The first approach in developing the system proposed in this study is to incorporate the sensor device into a portable clipped-device. The sensor that will be used is a three-axis accelerometer. Then an algorithm will be developed to detect an actual fall from a normal day activity using a PIC Microcontroller, and may also receive an interruption whether the sent information is a false alarm. Then the sensing device will send data into a remote monitoring device to alert that there is an occurrence of a fall. The remote monitoring device is programmed in such a way that it can detect multiple sensing devices. After receiving the information from the remote monitoring device, it forwards the information to a Monitoring Device Application Software via Arduino Board to record data using database system. Figure 3.2 shows a detailed block diagram of the fall detection and monitoring with database system.

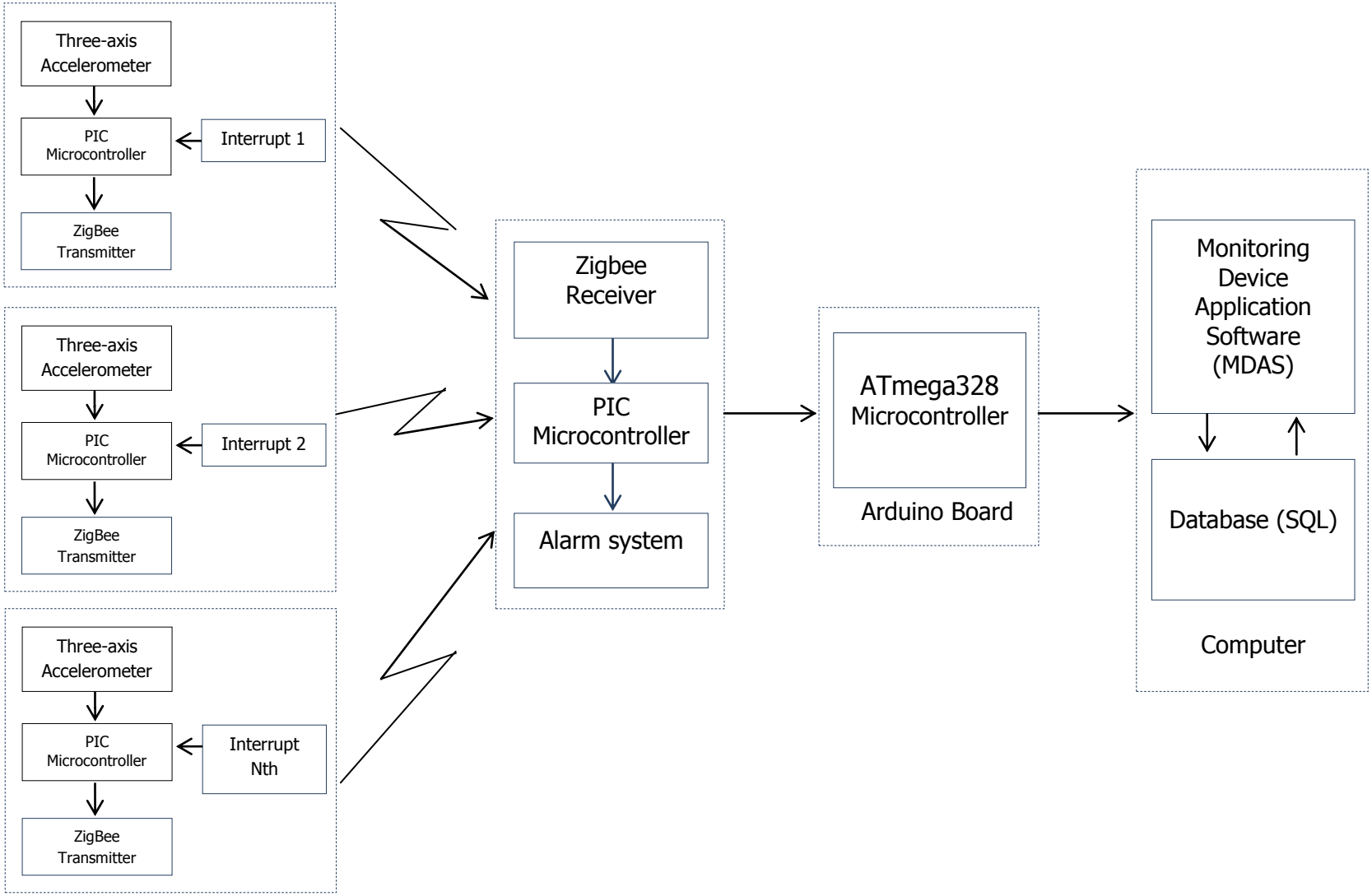

Figure 3.2 Detailed Block Diagram

The process begins with designing a convenient clip-on casing where the three-axis accelerometer module will be incorporated. The portability of the design will allow the patient to simply clip-on the device in their trunk. The three-axis accelerometer will be used to measure the change in acceleration for each normal activity of the user.

Then the device will be tested and calibrated first to gather signals needed for the design of the algorithm for fall detection. The process is exemplified in Figure 3.3. The data collected will be stored into the microcontroller and a corresponding algorithm will be applied to determine a normal day activity from an incidental fall. These data include the change in acceleration while the person is doing normal day activities such as walking, sitting on a chair, getting up from bed, etc.

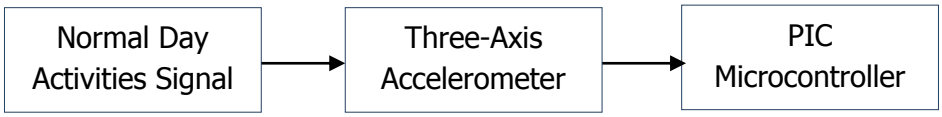

Figure 3.3 Collecting signals for the fall detection algorithm

After the gathering the accelerometer readings for typical daily activities and storing it into the microcontroller, the algorithm for fall detection will be developed as shown in Figure 3.4. The process is continuous to make it a real-time system that can detect a fall incident at any given time.

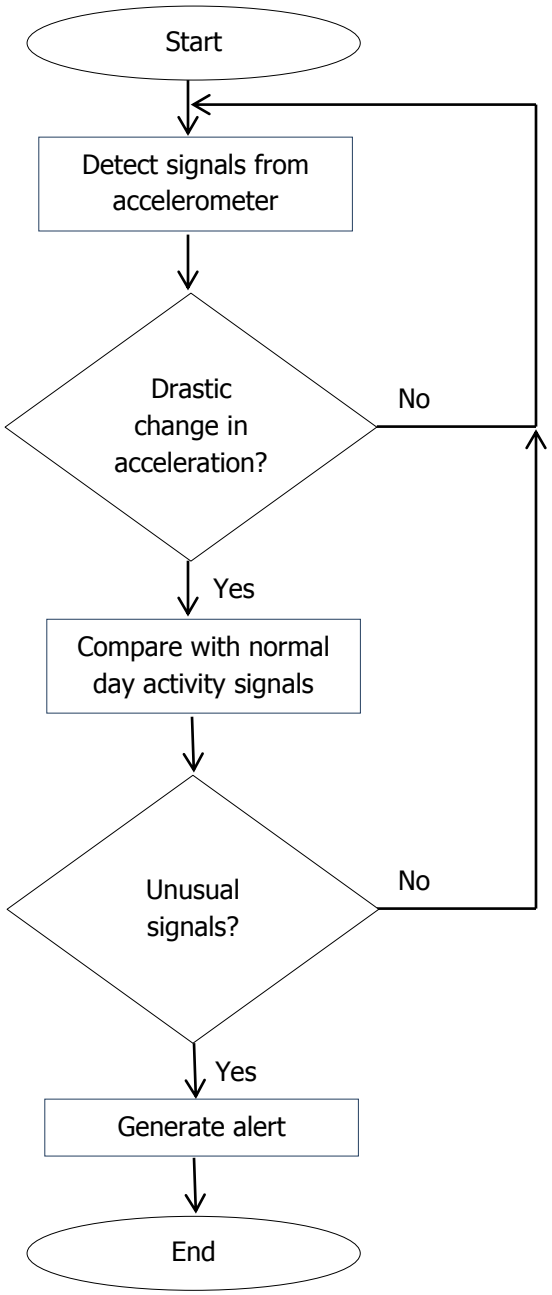

Figure 3.4 Fall detection algorithm

The signals from the three-axis accelerometer will be sent into the microcontroller. If a drastic change in acceleration is observed, the signals will be processed and will be compared with the usual daily activity signals. The

microcontroller will indicate a fall incident if the input signals show very distinct characteristics from the normal activity signals. In the event of a fall, the device will emit a sound alarm to notify the patient wearing the device that the incident has already been reported to the remote monitoring device and a record will be added into the database. The transmission will be discussed in the later part of this chapter.

To ensure the consistency of the device, a 'false alarm' module will be added to it. There may be instances where the person had almost fell but was able to instantly recover from the fall, thus a button will be triggered in case the incident does not need immediate attention or it is a false fall. The integration of this module with the system is described in Figure 3.5.

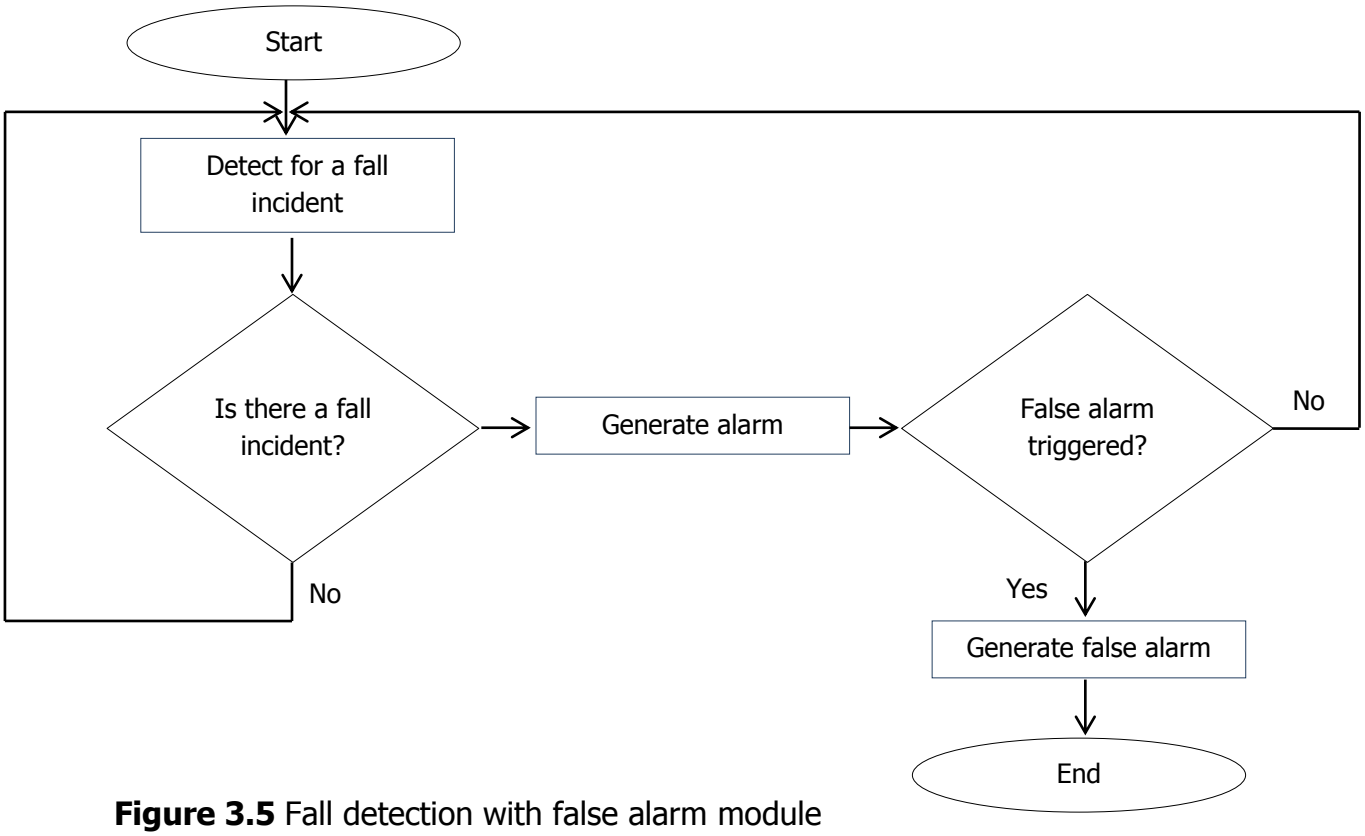

Figure 3.5 Fall detection with false alarm module

If a fall has been detected by the device, the system will generate an alarm. The patient can also send an interrupt signal indicating that it is a false fall or if he/she doesn't need any immediate assistance.

The last part in the development of the system is the wireless transmission of the fall alarm and interrupts using ZigBee technology. It is embedded together with the three-axis accelerometer module, and a remote receiving system will be used for monitoring the patient's activities. ZigBee is used in this paper because it is designed for wireless controls and sensors. It allows wireless one-way communication and travels across greater distances and handles many sensors that can be linked to perform different tasks. ZigBee is a wireless protocol that allows users to build medium to large networks of sensors and controllers. It transmits packets from the accelerometer and microcontroller to the receiver via wireless connection. The receivers are characterized by high stability and reliability of performance, and are generally adapted for remote control and monitoring. It will be used to accept signals or packets from the accelerometer and microcontroller through the ZigBee transmitter and then translate signals into a usable form for the destination.

The generated signals from the microcontroller will be passed to the ZigBee transmitter and the data will be sent to the receiver via wireless connection. The remote monitoring device consists of the receiver and alarm mechanism, and connected to a personal computer with a Monitoring Device Application Software via Arduino Board. Upon receiving the data from the

transmitter, the receiver translates the signal and the system will indicate that there is an occurrence of a fall through LCD display and buzzer. In addition, the received signal from the microcontroller will be recorded in a database via Arduino Board. The database will record the Patients' Number, Name, Room Number, Fall or False Fall, as well as what kind of assistance or medical procedures will be given. It may also be possible that an interruption signal will be received from the device if the false fall alarm is triggered. Thus, two alarm signals will be the output of the remote monitoring device.

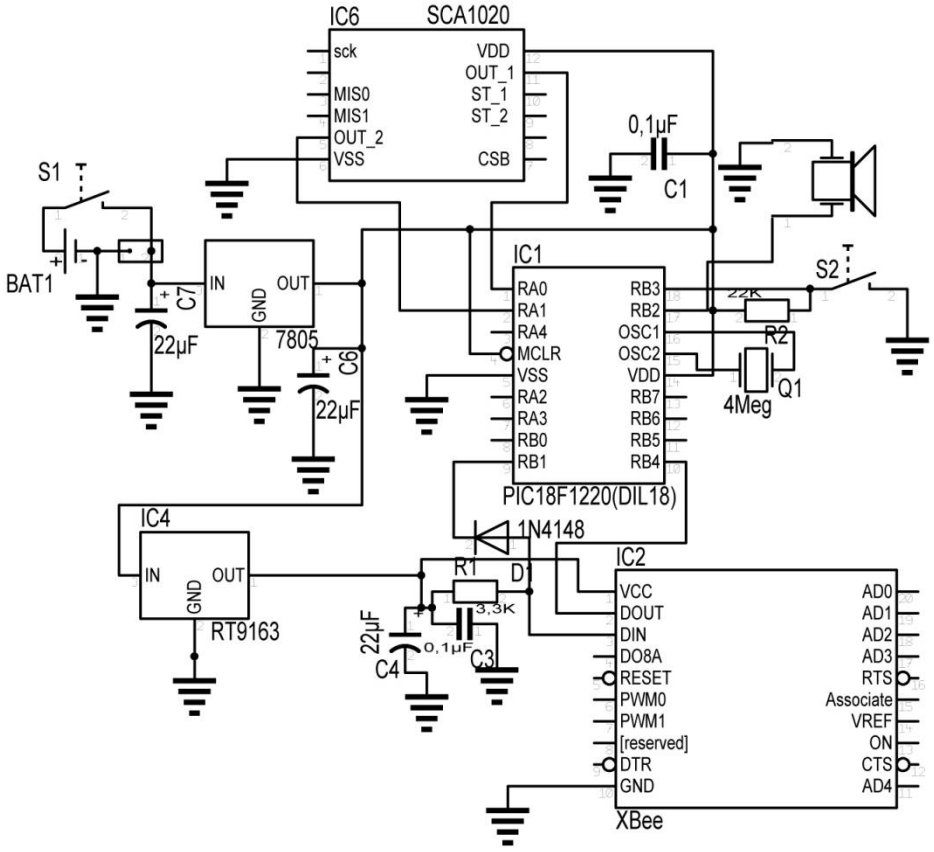

Figure 3.6.1 Fall Detection Device Schematic Diagram

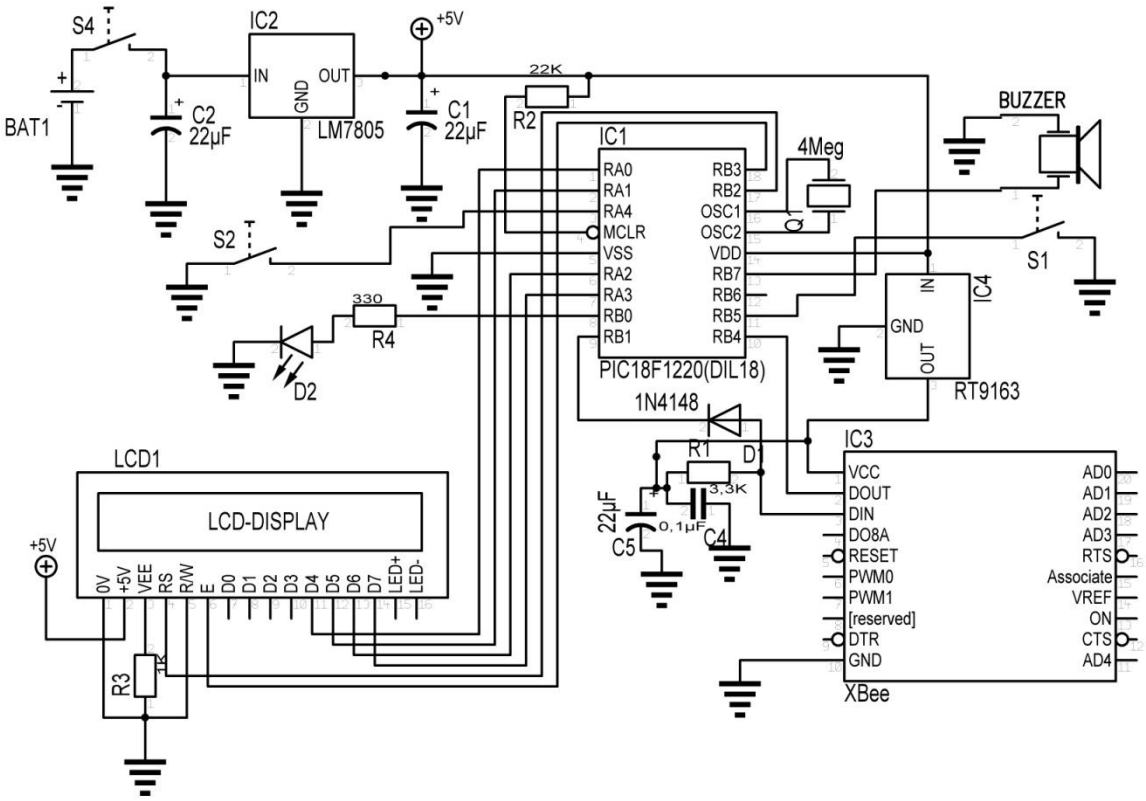

Figure 3.6.2 Monitoring Device Schematic Diagram

Figures No. 3.6.1 and 3.6.2 show the interconnection of the components for the sensor and monitoring devices, respectively. PIC18F1220 with 18 pins was used for both the circuits to process the information. The accelerometer was used to detect the change in orientation of the patient, and the signals were processed by the microcontroller. If an alarm is triggered, a signal is transmitted via ZigBee transmitter. It is then received by the monitoring device using a ZigBee receiver and the microcontroller initializes the alarm with a buzzer and the LCD display.

Software Development

The application used in developing the software part of the system is Microsoft .NET Framework. The windows application is built using Visual C# which supports access to a serial port. The programmer used SQL Server to access the database. The database is created using the .NET Framework Data Provider for SQL Server.

The signals from the receiver were accessed using the I/O pins of the Arduino Board. This board's microcontroller was programmed using the Arduino programming language, which was similar to C or C++ language. The board is connected to the computer using a USB port and the C# application processes the signals sent by the Arduino Board.

The researchers' first step in developing the software is to develop the flowchart of the system to visualize the flow of information. The whole system is considered including the signals from the receiver and the database. Figure 3.7 illustrates the flowchart.

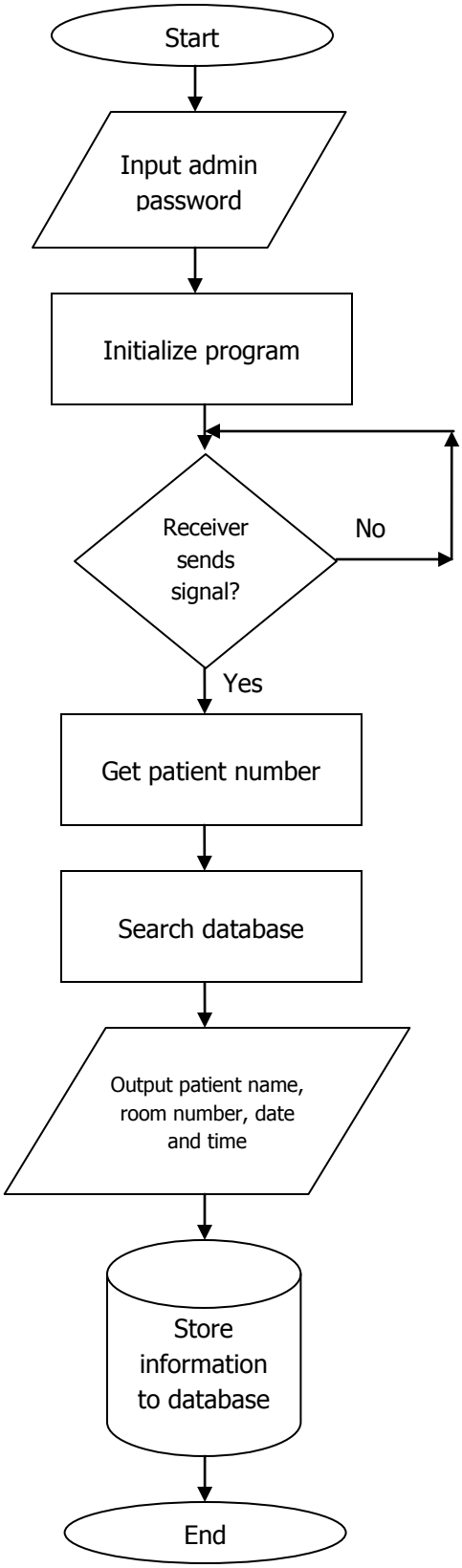

Figure 3.7 Windows Application Flowchart

The system has only one administrator account to manage the software. Only the password can be modified but the user name is set constant. The administrator can manage the record of patients included in the system. A primary key is used which is the patient number to identify which device is worn by the patient. The patient number is the same with the device number. So whenever a patient will be released from the hospital, the administrator can delete the information such as the name and room number that is assigned to a patient number, and then add a new one if it will be used.

Upon running the program, the user is asked to enter the administrator password to access the program. Then the monitoring device waits for any alarm trigger that signals a fall incident. The sensor device sends a signal to the receiver and the Arduino board will distinguish the patient number based on the activated port. The program then processes the information and searches the database. It then displays the patient's name, room number, the time, and date of the incident. These are also recorded in another database for further use.

Prototype Development

After designing the block diagram of the system and selecting the components to be used, the researchers have developed the prototype by following these certain procedures:

1. Identify all the components that will be used for the assembly of the device. Provide a complete list of the materials.

2. Design the circuit diagram. Show all the interconnections of the components listed for the sensor device and the monitoring device. Multisim was used to design the circuit.
3. Construct the layout of the circuit in PCB Wizard. Place all the components and the connections of the circuits. Print the layouts in a transparent film for photo etching.
4. Etch the printed circuit board based on the printed layout. Test the board for continuity to avoid any malfunctions in the circuit. Drill the board properly where the components will be mounted. Solder all of the components based on their connections.
5. Program both of the PIC18F1220 microcontrollers based on the fall detection algorithm and the receiving of data in the monitoring unit. Proton IDE was used to program the microcontrollers.
6. After debugging the program, it is then compiled and a hex file is generated. This is the format that is read by the microcontroller.
7. Burn the hex file to the microcontroller using PIC Kit 2. Test the devices if the expected outputs are met.
8. Connect the output port of the monitoring device to the Arduino board. The board used is Arduino Deumilanove with ATmega328.

Table 3.1 shows the components used in building the prototype and the bill of materials.

QTY:	ITEM NAME:	Description	COST
1 PC.	Three Axis Accelerometer	SCA3000	650.00
3 PC.	Zigbee 2Transmitter/1Reciever	XBee	2,775.00
1 PC.	Microcontroller	PIC18F1220	205.00
1 PC.	IC Socket	18-Pin	30.00
5 Pcs.	Capacitor	1k µF	5.00
2 Pcs.	Crystal Sine Generator	4MHz	2.50
2 Pcs.	Switching Diode	1N4148	2.00
3 Pcs.	Push Button	-	15.00
1 Pc.	Buzzer	-	30.00
1 PC.	LED	-	3.00
2 Pcs.	Voltage Regulator	RT9163	50.00
5 Pcs.	Resistor	22K Ω	5.50
3 Pcs.	Casing	-	60.00
1 Pc.	LCD Display	2x16	450.00
2 Pcs.	Battery	9 V	120.00
1 Ps.	Slide Switch	-	6.00
1 Pc.	Board w/ Microcontroller	Arduino Duemilanove with ATmega328	875.00
1 Pc.	Connector M/F	2-Pin	10.00
1 Pc.	Connector M/F	4-Pin	15.00
1 Pc.	Connector M/F	8-Pin	25.00
2 Pcs.		LE50	10.00
			TOTAL: Php 5344.00

Table 3.1 Bill of Materials

Monitoring Device Application Software

The monitoring software where the details regarding the patients are displayed is built with a Graphical User Interface. Visual Studio C# was used to develop the GUI-based windows application. The main form of the program is shown in Figure 3.8.

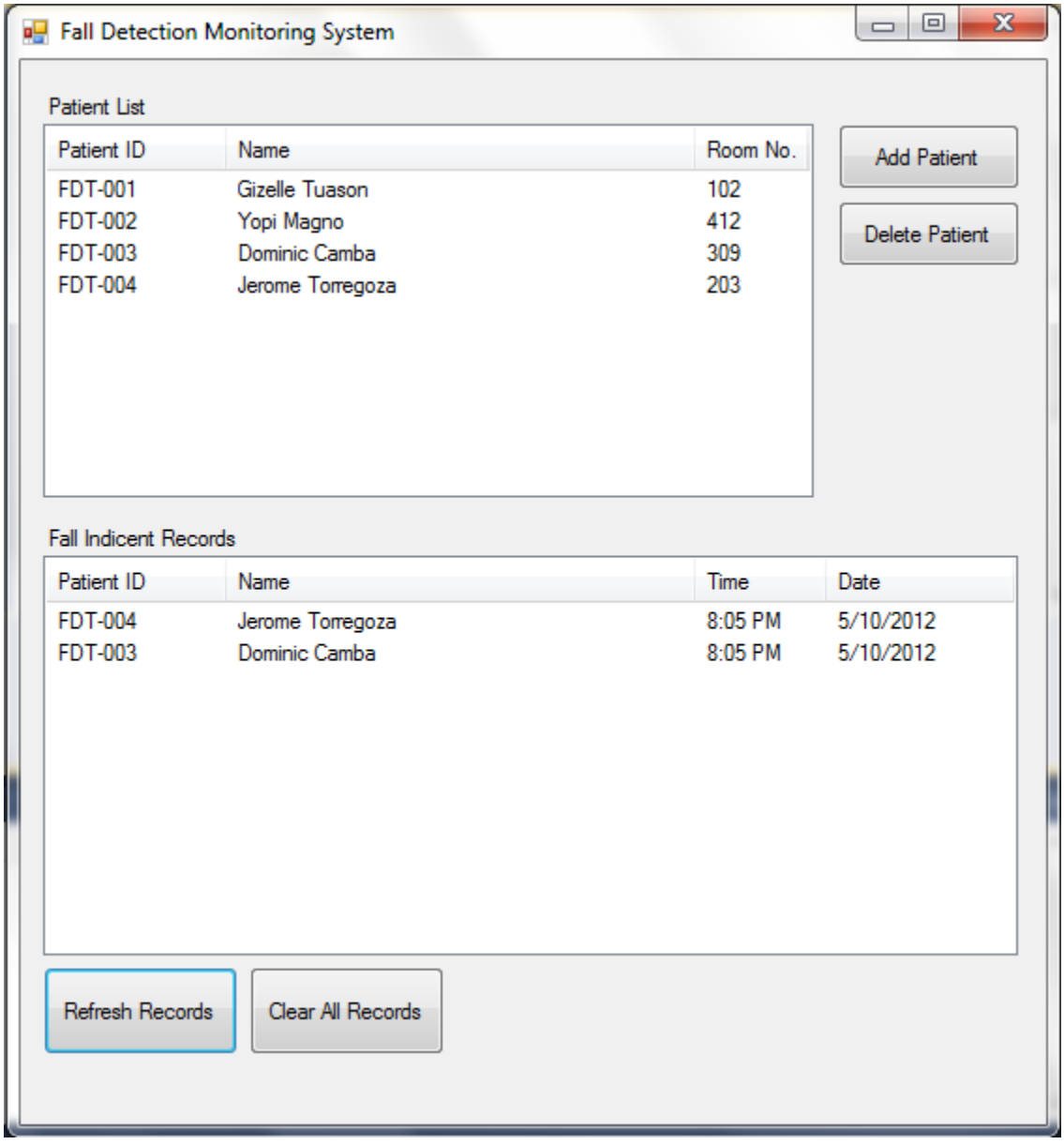

Figure 3.8 Monitoring Device Application Main Form

Figure 3.8 shows the main form of the program. There is a list where the patient's ID, name, and room of all the patients wearing the sensor devices are displayed. Another list is created for the list of the incidents. The time and date of the incident are recorded in the database. The user can refresh the list if ever another incident has occurred. The list can also be cleared from the form and from the database, and a warning window is added to verify if the clearing will be performed.

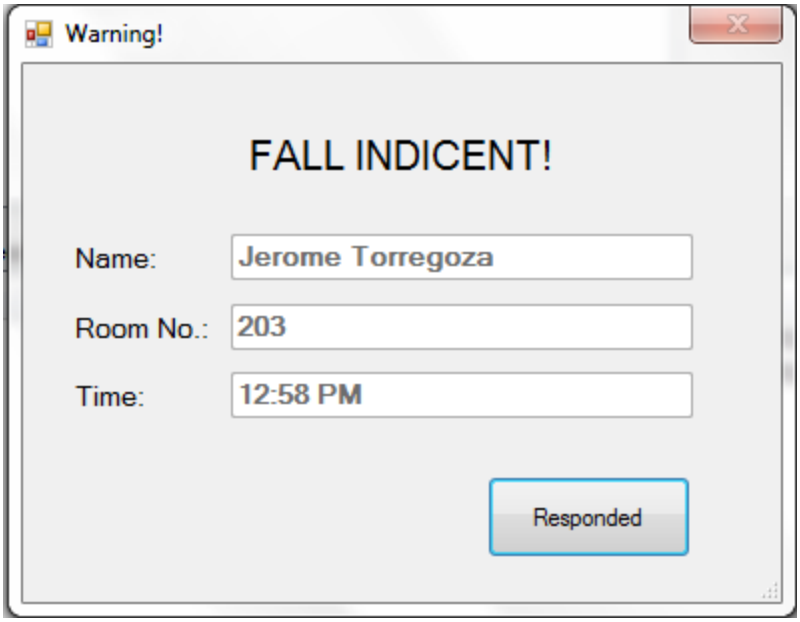

Figure 3.9 Fall Incident Notification Form

The administrator is notified when a fall has occurred and details regarding the patient is shown in a form in Figure 3.9. The form will only be closed if the administrator has already responded to the incident. The incident will be recorded to the database.

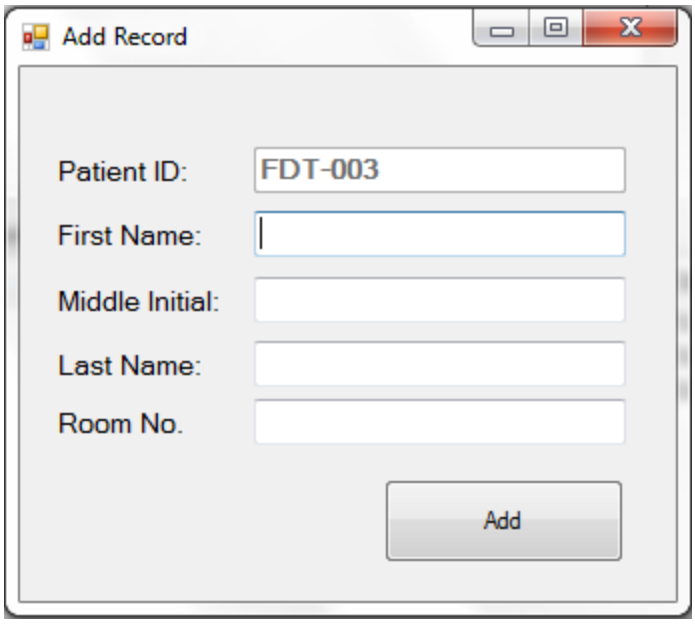

Figure 3.10 Add New Record Form

If the administrator wishes to add another record, the form in Figure 3.10 is used. The patient's ID is predefined based on the available device for use.

Chapter 4

TESTING, PRESENTATION, AND INTERPRETATION OF DATA

This chapter discusses the testing procedures made for the system to assess if the stated objectives in the first chapter are met. Different testing types and procedures were implemented to the prototype after the assembly.

The researchers provided three testing procedures to test the efficiency of the device. The first test is to identify a certain activity if it is a fall or a non-fall; second test is for the response time of the system or how fast the device will send an alarm to the remote monitoring device with respect to the type of fall; and the third test is for the response time of the system depending on the distance of the device from the remote monitoring device.

The fall detection device must be placed or clipped on the trunk of the user before turning it on to calibrate the three-axis accelerometer. Then after turning on the remote monitoring device, the user can perform his/her usual activities. For the purpose of testing, the user will imitate an occurrence of a fall and the remote monitoring device will be observed if it will indicate an alarm or not.

The alarm consists of an LCD display and a buzzer. If the system notifies an occurrence of a fall, then the person monitoring the user can press a button on the remote monitoring device to stop the sound of the alarm if he/she has already been notified.

Treatment of Data

The researchers used the following formula to calculate the percentage of detecting an actual occurrence of a fall based from the data gathered. With these data, the researchers can determine the percentage of detection of the device for a particular activity. The percentage of detection can be calculated using the following formula:

$$\%\ Detection = \frac{\sum_{i=m}^{n}\left(\frac{No.\ of\ Correct\ detection}{No.\ of\ Actual\ Fall\ or\ Non-Fall\ Occurrence}\right)_i}{n}\ x\ 100\%$$

Also, the average response time of the monitoring device to generate an alarm will also be computed to establish if the use of Zigbee technology will be more effective, with respect to the type of fall and the distance of the transmitter from the receiver. The following formula will be used:

$$Average\ Response\ Time = \frac{\sum_{i=m}^{n} tf_i}{n}$$

where tf_i is the response time with respect to the type of fall,

$$Average\ Response\ Time = \frac{\sum_{i=m}^{n} td_i}{n}$$

and $td_i$is the response time with respect to distance.

Detection of Fall Testing

For the first test procedure, the researchers will distribute the thirty samples by age and by capability. Ten, fifteen, and five samples will come from children (1 – 9 years old), adolescent-and-above (10 years old and above), and

persons with disability, respectively. Each sample will follow the type of activity provided by the researcher. The device will detect for that particular activity if it is a fall or not. Table 4.1.1 and Table 4.1.2 are used to record the data.

Table 4.1.1 Detection of Fall Test for Fall Activities

Trial	Type of Person	Detection (Fall/Non-fall)			
		Fall While Walking	**Fall While Standing**	**Fall From Bed**	**Fall From Chair**
1	Children (1-9 yrs old)	Fall	Fall	Fall	Fall
2		Fall	Fall	Fall	Fall
3		Fall	Fall	Fall	Fall
4		Fall	Fall	Fall	Fall
5		Fall	Fall	Fall	Fall
6		Fall	Fall	Fall	Fall
7		Fall	Fall	Fall	Fall
8		Fall	Fall	Fall	Fall
9		Fall	Fall	Fall	Fall
10		Fall	Fall	Fall	Fall
11	Adolescent (10 and above)	Fall	Fall	Fall	Fall
12		Fall	Fall	Fall	Fall
13		Fall	Fall	Fall	Fall
14		Fall	Fall	Fall	Fall
15		Fall	Fall	Fall	Fall
16		Fall	Fall	Fall	Fall
17		Fall	Fall	Fall	Fall
18		Fall	Fall	Fall	Fall
19		Fall	Fall	Fall	Fall
20		Fall	Fall	Fall	Fall
21		Fall	Fall	Fall	Fall
22		Fall	Fall	Fall	Fall
23		Fall	Fall	Fall	Fall
24		Fall	Fall	Fall	Fall
25		Fall	Fall	Fall	Fall
26	Persons with Disability	Fall	Fall	Fall	Fall
27		Fall	Fall	Fall	Fall
28		Fall	Fall	Fall	Fall

29		Fall	Fall	Fall	Fall
30		Fall	Fall	Fall	Fall

Table 4.1.1 (Detection of Fall Test for Fall Activities) shows the response of the devices to a particular activity if a fall happens. These activities are fall incidents while walking, standing, from stairs, and from chair. Based on the results, the formula for percentage of detection will then be applied for the fall and non-fall activities. It can be clearly seen that the device has successfully detected all kinds of fall that were set by the researchers, but some non-fall activities were detected as fall occurrence. The result is that the device can detect a fall from all the activities provided giving the researcher a 100% detection.

Table 4.1.2 Detection of Fall Test for Non-fall Activities

`Trial	**Type of Person**	**Detection (Fall/Non-fall)**			
		Walking	**Sitting**	**Walking Upstairs**	**Walking Downstairs**
1	Children (1-9 yrs old)	Non-fall	Non-fall	Non-fall	Fall
2		Non-fall	Fall	Non-fall	Fall
3		Non-fall	Non-fall	Non-fall	Non-fall
4		Non-fall	Non-fall	Non-fall	Non-fall
5		Non-fall	Non-fall	Non-fall	Non-fall
6		Non-fall	Non-fall	Non-fall	Non-fall
7		Non-fall	Fall	Non-fall	Fall
8		Non-fall	Non-fall	Non-fall	Fall
9		Non-fall	Fall	Non-fall	Fall
10		Fall	Fall	Fall	Fall
11	Adolescent (10 and above)	Non-fall	Non-fall	Non-fall	Fall
12		Non-fall	Non-fall	Non-fall	Non-fall
13		Non-fall	Non-fall	Fall	Fall
14		Non-fall	Non-fall	Non-fall	Fall

15		Fall	Non-fall	Fall	Fall
16		Non-fall	Non-fall	Non-fall	Non-fall
17		Non-fall	Non-fall	Non-fall	Non-fall
18		Non-fall	Non-fall	Non-fall	Non-fall
19		Non-fall	Non-fall	Non-fall	Non-fall
20		Non-fall	Non-fall	Non-fall	Non-fall
21		Non-fall	Fall	Fall	Fall
22		Non-fall	Non-fall	Fall	Non-fall
23		Non-fall	Non-fall	Non-fall	Fall
24		Non-fall	Non-fall	Non-fall	Fall
25		Non-fall	Fall	Non-fall	Fall
26	Persons with Disability	Non-fall	Non-fall	Fall	Fall
27		Non-fall	Non-fall	Non-fall	Fall
28		Non-fall	Non-fall	Non-fall	Non-fall
29		Non-fall	Non-fall	Fall	Non-fall
30		Non-fall	Non-fall	Non-fall	Non-fall

Table 4.1.2 (Detection of Fall Test for Non-Fall Activities) shows if the device will detect a fall or alarms even though the particular activity is a non-fall. These activities are walking, sitting, walking upstairs and downstairs. For walking – 93.33%; sitting – 80.00%; walking upstairs – 76.67%; and walking downstairs – 46.67%. The average percentage of detection is 74.17%. Of all the activities that were tested, walking downstairs would not reach the acceptance to meet the objective. So as a solution, a false fall alarm was added to the system. The participants can give information to the remote monitoring user that a false fall happened. One good reason for a false detection of the device is the sensitivity of it. The researchers set the degree of detection to 80° to 90°, which is too high. So, the researchers can lower the degree of detection to change the percentage of the outcomes.

Chapter 5

CONCLUSION AND RECOMMENDATION

This chapter presents the conclusion of the study and implementation of the design project entitled, "Human Fall Detection with Monitoring and Database System", and the recommendations from the researchers to further improve the system.

Conclusion

The objectives of this study are to create a low cost monitoring device that can support two (2) or more fall detection devices using an accelerometer and a microcontroller to sense the orientation of the patient, and ZigBee technology for the wireless transmission of the signals; to develop a software that will read the signals from the monitoring device and display the patient's name, room number, time of event, and to deploy a database system that will store the information from the Monitoring Device Application Software (MDAS) for further medical use.

After researching and developing the existing fall detection system, based from the results of each test, the researchers found out that the device can support two or more sensor devices, which means the implementation of the system may be considered low-cost since users or implementers need only one

monitoring device. In addition, the devices have provided a 100% detection of fall giving the researchers as well as the users a high acceptance for the device.

The positioning of the device in the user's body is also significant to distinguish a fall from a non-fall. Since it is clipped on the trunk on the user which is the center of gravity of the body, it is also more convenient to be worn on a daily basis because it cannot cause distraction to our daily activities, unlike the previous devices were embedded into belt-types, pendant-types, or even worn at the wrist.

The researchers also considered the notifications from the Monitoring Device Application Software wherein two (2) or more sensor devices will send an alarm signal at the same time. After testing the capability of the Application Software in notifying incidents at the same time, the researchers found out that the delay between two (2) or more incident is almost negligible.

Recommendation

Further studies may be done to incorporate the fall detection device with a GPS module to easily identify the location of the person where he/she experienced the fall. The remote monitoring device may also be provided with a larger screen to display a map which shows the boundary of the location of the user and the system will generate an alarm and track the user in the map. This may be more effective if the system is used on a wider area or in a hospital building.

Another innovation that can be done to the project is that the remote monitoring device can send a notification to a mobile phone via SMS if a fall has been detected. This can be very effective for home use. But these two stated improvements can also be added simultaneously to the system to provide a better fall detection and monitoring device.

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APPENDICES

APPENDIX A

Operation's Manual

System Requirements

The following are the system requirements needed to be able to operate the software part of the monitoring device:

1. Operating System: Windows XP or newer version
2. USB Port
3. Microsoft .NET Framework

Installation Procedure

1. Assign each sensor devices to the respective patients.
2. Allow the patients to secure the sensor devices in their trunk.
3. Setup the monitoring device near a laptop or a PC.
4. Connect the output ports of the monitoring device to the Arduino board.
5. Connect the Arduino board to the USB port of a laptop or a PC.
6. Install the Microsoft .NET Framework in the laptop or PC.

User's Manual

1. Turn on the monitoring device connected to the laptop or PC.
2. Wait for the LCD to output "READY…"
3. Run the software of the monitoring device in the laptop or PC.
4. Input the correct password for the administrator account to be able to access the software and manage the monitoring device.
5. Turn on the sensor devices worn by the patients.
6. Wait for any fall incidents. If the alarm is triggered, take note of the notification displayed in the laptop or PC regarding the information about the patient. The buzzer will alarm and a message will also be displayed in the LCD of the monitoring device, "FALL DETECTION".
7. Click "Responded" in the notification form after attending to the need or after assisting the patient. The form will not close if the button is not clicked.
8. Take note that there are multiple devices in the system. The monitoring device may receive more than one alarm simultaneously. The program will also show notifications simultaneously, but each will appear in the sequence that the signals are received. The notifications must be attended and responded at the same time.
9. Turn off all of the devices if the system will not be in used.

Troubleshooting Guides and Procedures

1. If the LCD in the monitoring device has no output,
    1.1 Check if the voltage source is still 9V, if not, charge the device using the charger.
2. If the sensor device is not working properly,
    2.1 Check the solution in number 1.
    2.2 Place the sensor device only along the trunk of the body.
    2.3 Use the false alarm button if there are unwanted triggers in the alarm.
3. If the laptop or PC cannot detect the monitoring device,
    3.1 Check the connection of the output port of the monitoring device with the Arduino board.
    3.2 Check the USB connection of the Arduino board with the USB port of the laptop of PC.
4. If the software in the laptop or PC does not load or initialize,
    4.1 Check for the solutions in number 3.
    4.2 If the rest fails, restart the laptop or PC because the problem might be regarding the operating system.

Error Definitions

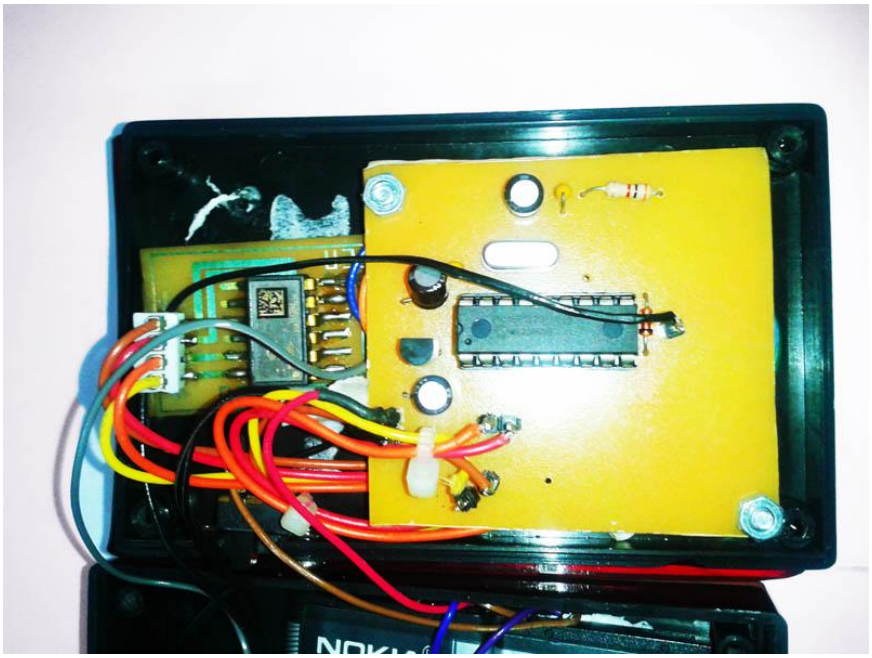
1. Insufficient battery.
2. Failure in the operating system running the software.
3. Wrong placement of the sensor device.
4. Devices not turned on.
5. Faulty connections of the device.
6. Human error.

APPENDIX B

Pictures of Prototype

Fall Detection and Monitoring Device with Charger

Monitoring Device Circuit Board



Sensor Device Circuit Board

Fall Detection and Monitoring Device

APPENDIX C

Program Listing

Windows Form Application

Form1.cs

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Windows.Forms;
using System.Data.SqlClient;
using System.IO.Ports;

namespace DesignProgram
{
   public partial class form_Main : Form
   {
      private delegate void LineReceivedEvent(string line);
      form_Add Add = new form_Add();
      form_Login Login = new form_Login();
      SqlConnection myConnection = new SqlConnection("Data
Source=.\\SQLEXPRESS;AttachDbFilename=C:\\Users\\pc owner\\Documents\\School\\DESIGN
1\\FallDetection\\DesignProgram\\DesignProgram\\PatientsDB.mdf;Integrated Security=True;User
Instance=True");

      int index=0;
      string id;

      public form_Main()
      {
         InitializeComponent();
         btn_delete.Enabled = false;
         this.CenterToScreen();
         try
         {
            SqlDataReader myReader = null;
            SqlCommand myCommand = new SqlCommand("select * from PatientsTable where
Name!="", myConnection);

            myConnection.Open();
            myCommand.CommandText = "select * from FallTable";
            myReader = myCommand.ExecuteReader();
            while (myReader.Read())
            {
```

```
                string[] subitems = { myReader["FName"].ToString(), myReader["Time"].ToString(),
myReader["Date"].ToString() };
                listView1.Items.Add(myReader["FID"].ToString(), index).SubItems.AddRange(subitems);
            }
            myConnection.Close();

        }
        catch (Exception e)
        {
            MessageBox.Show(e.ToString());
        }
    }

    public string id_send
    {
        get { return id; }
    }

    private void btn_fall2_Click(object sender, EventArgs e)
    {
        form_Warning Warning = new form_Warning();
        id = "FDT-003";
        Warning.id_receive = id_send;
        Warning.ShowDialog();
    }

    private void btn_fall1_Click_1(object sender, EventArgs e)
    {
        form_Warning Warning = new form_Warning();
        id = "FDT-004";
        Warning.id_receive = id_send;
        Warning.ShowDialog();
    }

    private void btn_refresh_Click(object sender, EventArgs e)
    {
        listView1.Items.Clear();
        myConnection.Open();
        SqlDataReader myReader = null;
        SqlCommand myCommand = new SqlCommand("select * from FallTable", myConnection);

        myReader = myCommand.ExecuteReader();
        while (myReader.Read())
        {
            string[] subitems = { myReader["FName"].ToString(), myReader["Time"].ToString(),
myReader["Date"].ToString() };
            listView1.Items.Add(myReader["FID"].ToString(), index).SubItems.AddRange(subitems);
        }
        myConnection.Close();
    }

    private void form_Main_FormClosing(object sender, FormClosingEventArgs e)
    {
        if (serialPort1.IsOpen == true)
        {
            serialPort1.Close();
```

```
    }
    Login.Close();
}

private void btn_clear_Click(object sender, EventArgs e)
{
    DialogResult result;
    string message = "Are you sure you want to clear all the records?";
    string caption = "Warning";
    result = MessageBox.Show(message, caption, MessageBoxButtons.YesNo);
    if (result == DialogResult.Yes)
    {
        myConnection.Open();
        SqlCommand myCommand = new SqlCommand("Delete from FallTable", myConnection);
        myCommand.ExecuteNonQuery();
        myConnection.Close();
        listView1.Items.Clear();
    }
}

private void list_records_SelectedIndexChanged(object sender, EventArgs e)
{
    btn_delete.Enabled = true;
}

private void serialPort1_DataReceived(object sender, SerialDataReceivedEventArgs e)
{
    if (serialPort1.IsOpen == false)
    {
        serialPort1.Open();
        MessageBox.Show("Opening port");
    }
    string line = serialPort1.ReadLine();
    this.BeginInvoke(new LineReceivedEvent(LineReceived), line);
}

private void LineReceived(string line)
{
    form_Warning Warning = new form_Warning();
    if (line.Contains("101") == true)
    {
        id = "FDT-001";
        Warning.id_receive = id_send;
        Warning.ShowDialog();
    }
    if (line.Contains("102") == true)
    {
        id = "FDT-002";
        Warning.id_receive = id_send;
        Warning.ShowDialog();
    }
}

private void form_Main_Load(object sender, EventArgs e)
{
    try
```

```
            {
                serialPort1.Open();
            }
            catch (Exception eR)
            {
                MessageBox.Show(eR.ToString());
            }
        }

        private void btn_delete_Click(object sender, EventArgs e)
        {
            DialogResult result;
            string message = "Are you sure you want to delete the patient record?";
            string caption = "Warning";
            string id = list_records.SelectedItems[0].ToString();
            result = MessageBox.Show(message, caption, MessageBoxButtons.YesNo);
            if (result == DialogResult.Yes)
            {
                id = id.Remove(0, 15);
                id = id.Remove(7, 1);
                myConnection.Open();
                SqlCommand deleteCommand = new SqlCommand("update PatientsTable set Name = '',
Room ='' where ID ='" + id + "'", myConnection);
                deleteCommand.ExecuteNonQuery();
                list_records.Items.Clear();
                SqlDataReader myReader = null;
                SqlCommand myCommand = new SqlCommand("select * from PatientsTable where
Name!=''", myConnection);
                myReader = myCommand.ExecuteReader();
                while (myReader.Read())
                {
                    string[] subitems = { myReader["Name"].ToString(), myReader["Room"].ToString() };
                    list_records.Items.Add(myReader["ID"].ToString(),
index).SubItems.AddRange(subitems);
                }
                myConnection.Close();
            }
            btn_delete.Enabled = false;
        }

        private void btn_add_Click(object sender, EventArgs e)
        {
            myConnection.Open();
            SqlDataReader myReader = null;
            SqlCommand getIdCommand = new SqlCommand("select ID from PatientsTable where
Name='', myConnection);
            myReader = getIdCommand.ExecuteReader();
            while (myReader.Read())
            {
                id = myReader["ID"].ToString();
                if (id != "")
                {
                    Add.id_receive2 = id_send;
                    Add.Show();
                    break;
                }
```

```
            }

            if (id == "")
                MessageBox.Show("No device is available.");
            id = "";
            myConnection.Close();
        }

        private void form_Main_Activated(object sender, EventArgs e)
        {
            list_records.Items.Clear();
            myConnection.Close();
            myConnection.Open();
            SqlDataReader myReader = null;
            SqlCommand myCommand = new SqlCommand("select * from PatientsTable where
Name!='', myConnection);

            myReader = myCommand.ExecuteReader();

            while (myReader.Read())
            {
                string[] subitems = { myReader["Name"].ToString(), myReader["Room"].ToString() };
                list_records.Items.Add(myReader["ID"].ToString(), index).SubItems.AddRange(subitems);
            }
            myConnection.Close();
        }
    }
}
```

Form2.cs

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Windows.Forms;
using System.Data.SqlClient;
using System.Media;
using System.IO.Ports;


namespace DesignProgram
{
    public partial class form_Warning : Form
    {
        SqlConnection myConnection = new SqlConnection("Data
Source=.\\SQLEXPRESS;AttachDbFilename=C:\\Users\\pc owner\\Documents\\School\\DESIGN
1\\FallDetection\\DesignProgram\\DesignProgram\\PatientsDB.mdf;Integrated Security=True;User
Instance=True");
        string id, name, time, date;
        DateTime currTime = DateTime.Now;
```

```
        form_Main Main = new form_Main();
        public form_Warning()
        {
            InitializeComponent();
        }

        public string id_receive
        {
            set { id = value; }
        }

        private const int CP_NOCLOSE_BUTTON = 0x200;
        protected override CreateParams CreateParams
        {
            get
            {
                CreateParams myCp = base.CreateParams;
                myCp.ClassStyle = myCp.ClassStyle | CP_NOCLOSE_BUTTON;
                return myCp;
            }
        }

        private void btn_responed_Click(object sender, EventArgs e)
        {
            this.Close();
        }

        private void form_Warning_Load(object sender, EventArgs e)
        {
            try
            {
                myConnection.Open();
                SqlDataReader myReader = null;
                SqlCommand myCommand = new SqlCommand("select Name, Room from PatientsTable
where ID ='" + id + "'",
                                                      myConnection);
                myReader = myCommand.ExecuteReader();
                while (myReader.Read())
                {
                    name = myReader["Name"].ToString();
                    txtBox_name.Text = name;
                    txtBox_room.Text = myReader["Room"].ToString();
                    time = currTime.ToShortTimeString();
                    txtBox_time.Text = time;
                    date = currTime.ToShortDateString();
                }
                myConnection.Close();

                myConnection.Open();
                SqlCommand insertCommand = new SqlCommand("INSERT INTO FallTable (FID, FName,
Time, Date) VALUES ('" + id + "', '" + name + "', '" + time + "', '" + date + "')", myConnection);
                insertCommand.ExecuteNonQuery();
                myConnection.Close();
            }
            catch (Exception err)
            {
```

```
            MessageBox.Show(err.ToString());
        }
    }
  }
}
```

Form3.cs

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Windows.Forms;
using System.Data.SqlClient;

namespace DesignProgram
{
   public partial class form_Add : Form
   {
      string id, name, room;
      SqlConnection myConnection = new SqlConnection("Data
Source=.\\SQLEXPRESS;AttachDbFilename=C:\\Users\\pc owner\\Documents\\School\\DESIGN
1\\FallDetection\\DesignProgram\\DesignProgram\\PatientsDB.mdf;Integrated Security=True;User
Instance=True");

      public form_Add()
      {
         InitializeComponent();
      }

      public string id_receive2
      {
         set { id = value; }
      }

      private void form_edit_Load(object sender, EventArgs e)
      {
         this.CenterToScreen();
         txtBox_patientI.Text = id;
      }

      private void btn_add_Click(object sender, EventArgs e)
      {
         if (txtBox_fname.Text == "" || txtBox_lname.Text == ""
         || txtBox_room.Text == "")
            MessageBox.Show("Please complete the information.");
         else
         {
            name = txtBox_fname.Text + " " + txtBox_lname.Text;
            room = txtBox_room.Text;
            myConnection.Open();
```

```
            SqlCommand addCommand = new SqlCommand("update PatientsTable set Name = '" +
name + "', Room = '" + room + "' where ID ='" + id + "'", myConnection);
            addCommand.ExecuteNonQuery();
            myConnection.Close();
            MessageBox.Show("New record successfully added!");
            txtBox_room.Clear();
            txtBox_patientI.Clear();
            txtBox_fname.Clear();
            txtBox_lname.Clear();
            this.Close();
        }
    }
  }
}
```

Form4.cs

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Windows.Forms;

namespace DesignProgram
{
   public partial class form_Login : Form
   {
      string username = "admin", pass = "pass";

      public form_Login()
      {
         InitializeComponent();
         this.CenterToScreen();
         txtbox_pass.PasswordChar = '*';
      }

      private void btn_login_Click(object sender, EventArgs e)
      {
         if (txtbox_pass.Text != pass || txtbox_user.Text != username)
            MessageBox.Show("Invalid username or password!");
         else
         {
            form_Main Main = new form_Main();
            Main.Show();
            this.Hide();
         }
      }
   }
}
```

APPENDIX D

Datasheets

PIC18F1220/1320
Data Sheet

18/20/28-Pin High-Performance, Enhanced Flash Microcontrollers with 10-bit A/D and nanoWatt Technology

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MICROCHIP

PIC18F1220/1320

18/20/28-Pin High-Performance, Enhanced Flash MCUs with 10-bit A/D and nanoWatt Technology

Low-Power Features:

- Power Managed modes:
  - Run: CPU on, peripherals on
  - Idle: CPU off, peripherals on
  - Sleep: CPU off, peripherals off
- Power Consumption modes:
  - PRI_RUN: 150 µA, 1 MHz, 2V
  - PRI_IDLE: 37 µA, 1 MHz, 2V
  - SEC_RUN: 14 µA, 32 kHz, 2V
  - SEC_IDLE: 5.8 µA, 32 kHz, 2V
  - RC_RUN: 110 µA, 1 MHz, 2V
  - RC_IDLE: 52 µA, 1 MHz, 2V
  - Sleep: 0.1 µA, 1 MHz, 2V
- Timer1 Oscillator: 1.1 µA, 32 kHz, 2V
- Watchdog Timer: 2.1 µA
- Two-Speed Oscillator Start-up

Oscillators:

- Four Crystal modes:
  - LP, XT, HS: up to 25 MHz
  - HSPLL: 4-10 MHz (16-40 MHz internal)
- Two External RC modes, up to 4 MHz
- Two External Clock modes, up to 40 MHz
- Internal oscillator block:
  - 8 user-selectable frequencies: 31 kHz, 125 kHz, 250 kHz, 500 kHz, 1 MHz, 2 MHz, 4 MHz, 8 MHz
  - 125 kHz to 8 MHz calibrated to 1%
  - Two modes select one or two I/O pins
  - OSCTUNE – Allows user to shift frequency
- Secondary oscillator using Timer1 @ 32 kHz
- Fail-Safe Clock Monitor
  - Allows for safe shutdown if peripheral clock stops

Peripheral Highlights:

- High current sink/source 25 mA/25 mA
- Three external interrupts
- Enhanced Capture/Compare/PWM (ECCP) module:
  - One, two or four PWM outputs
  - Selectable polarity
  - Programmable dead time
  - Auto-Shutdown and Auto-Restart
  - Capture is 16-bit, max resolution 6.25 ns (TCY/16)
  - Compare is 16-bit, max resolution 100 ns (TCY)
- Compatible 10-bit, up to 13-channel Analog-to-Digital Converter module (A/D) with programmable acquisition time
- Enhanced USART module:
  - Supports RS-485, RS-232 and LIN 1.2
  - Auto-Wake-up on Start bit
  - Auto-Baud Detect

Special Microcontroller Features:

- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Flash/Data EEPROM Retention: > 40 years
- Self-programmable under software control
- Priority levels for interrupts
- 8 x 8 Single-Cycle Hardware Multiplier
- Extended Watchdog Timer (WDT):
  - Programmable period from 41 ms to 131s
  - 2% stability over VDD and Temperature
- Single-supply 5V In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via two pins
- Wide operating voltage range: 2.0V to 5.5V

Device	Program Memory		Data Memory		I/O	10-bit A/D (ch)	ECCP (PWM)	EUSART	Timers 8/16-bit
	Flash (bytes)	# Single-Word Instructions	SRAM (bytes)	EEPROM (bytes)					
PIC18F1220	4K	2048	256	256	16	7	1	Y	1/3
PIC18F1320	8K	4096	256	256	16	7	1	Y	1/3

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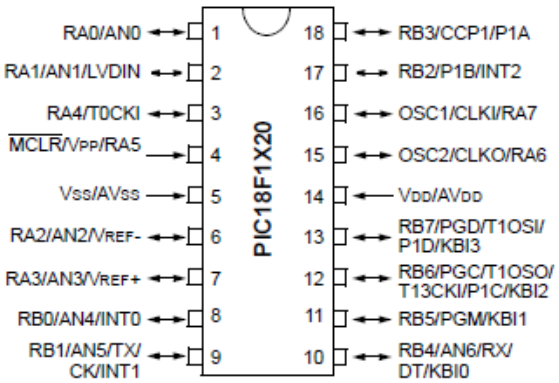
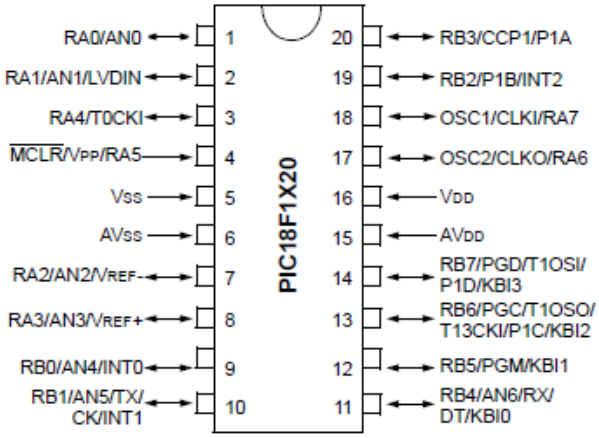
Pin Diagrams

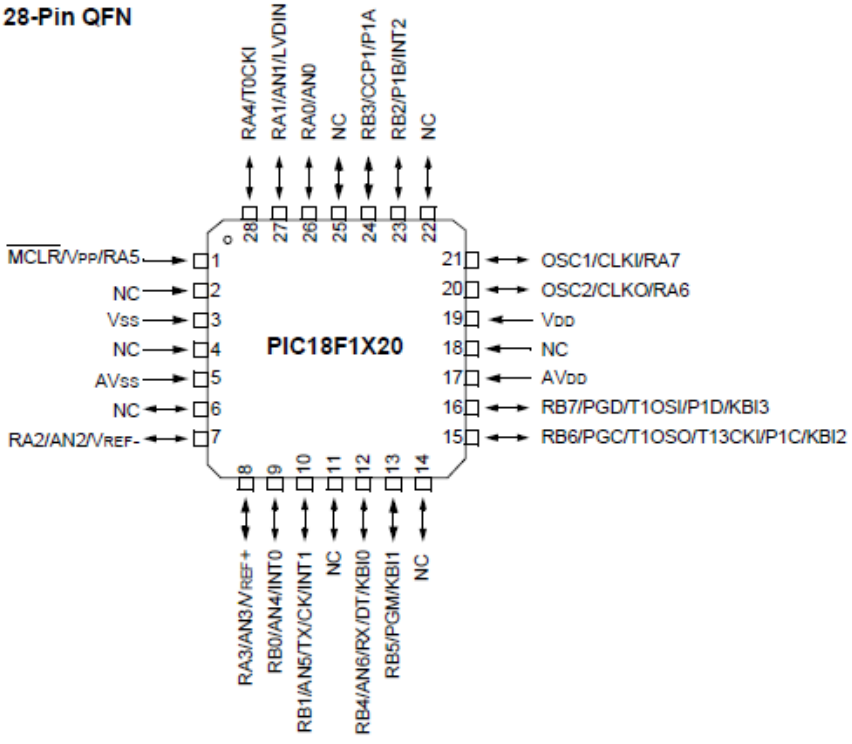
18-Pin PDIP, SOIC



20-Pin SSOP



28-Pin QFN



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1.0 DEVICE OVERVIEW

This document contains device specific information for the following devices:

- PIC18F1220
- PIC18F1320

This family offers the advantages of all PIC18 microcontrollers – namely, high computational performance at an economical price – with the addition of high endurance Enhanced Flash program memory. On top of these features, the PIC18F1220/1320 family introduces design enhancements that make these microcontrollers a logical choice for many high-performance, power sensitive applications.

1.1 New Core Features

1.1.1 nanoWatt TECHNOLOGY

All of the devices in the PIC18F1220/1320 family incorporate a range of features that can significantly reduce power consumption during operation. Key items include:

- **Alternate Run Modes:** By clocking the controller from the Timer1 source or the internal oscillator block, power consumption during code execution can be reduced by as much as 90%.
- **Multiple Idle Modes:** The controller can also run with its CPU core disabled, but the peripherals are still active. In these states, power consumption can be reduced even further, to as little as 4% of normal operation requirements.
- **On-the-fly Mode Switching:** The power managed modes are invoked by user code during operation, allowing the user to incorporate power-saving ideas into their application's software design.
- **Lower Consumption in Key Modules:** The power requirements for both Timer1 and the Watchdog Timer have been reduced by up to 80%, with typical values of 1.1 and 2.1 μA, respectively.

1.1.2 MULTIPLE OSCILLATOR OPTIONS AND FEATURES

All of the devices in the PIC18F1220/1320 family offer nine different oscillator options, allowing users a wide range of choices in developing application hardware. These include:

- Four Crystal modes, using crystals or ceramic resonators.
- Two External Clock modes, offering the option of using two pins (oscillator input and a divide-by-4 clock output), or one pin (oscillator input, with the second pin reassigned as general I/O).
- Two External RC Oscillator modes, with the same pin options as the External Clock modes.
- An internal oscillator block, which provides an 8 MHz clock (±2% accuracy) and an INTRC source (approximately 31 kHz, stable over temperature and V_{DD}), as well as a range of 6 user-selectable clock frequencies (from 125 kHz to 4 MHz) for a total of 8 clock frequencies.

Besides its availability as a clock source, the internal oscillator block provides a stable reference source that gives the family additional features for robust operation:

- **Fail-Safe Clock Monitor:** This option constantly monitors the main clock source against a reference signal provided by the internal oscillator. If a clock failure occurs, the controller is switched to the internal oscillator block, allowing for continued low-speed operation, or a safe application shutdown.
- **Two-Speed Start-up:** This option allows the internal oscillator to serve as the clock source from Power-on Reset, or wake-up from Sleep mode, until the primary clock source is available. This allows for code execution during what would otherwise be the clock start-up interval and can even allow an application to perform routine background activities and return to Sleep without returning to full power operation.

1.2 Other Special Features

- **Memory Endurance:** The Enhanced Flash cells for both program memory and data EEPROM are rated to last for many thousands of erase/write cycles – up to 100,000 for program memory and 1,000,000 for EEPROM. Data retention without refresh is conservatively estimated to be greater than 40 years.
- **Self-programmability:** These devices can write to their own program memory spaces under internal software control. By using a bootloader routine located in the protected Boot Block at the top of program memory, it becomes possible to create an application that can update itself in the field.
- **Enhanced CCP module:** In PWM mode, this module provides 1, 2 or 4 modulated outputs for controlling half-bridge and full-bridge drivers. Other features include auto-shutdown, for disabling PWM outputs on interrupt or other select conditions and auto-restart, to reactivate outputs once the condition has cleared.
- **Enhanced USART:** This serial communication module features automatic wake-up on Start bit and automatic baud rate detection and supports RS-232, RS-485 and LIN 1.2 protocols, making it ideally suited for use in Local Interconnect Network (LIN) bus applications.
- **10-bit A/D Converter:** This module incorporates programmable acquisition time, allowing for a channel to be selected and a conversion to be initiated without waiting for a sampling period and thus, reduce code overhead.
- **Extended Watchdog Timer (WDT):** This enhanced version incorporates a 16-bit prescaler, allowing a time-out range from 4 ms to over 2 minutes that is stable across operating voltage and temperature.

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1.3 Details on Individual Family Members

Devices in the PIC18F1220/1320 family are available in 18-pin, 20-pin and 28-pin packages. A block diagram for this device family is shown in Figure 1-1.

The devices are differentiated from each other only in the amount of on-chip Flash program memory (4 Kbytes for the PIC18F1220 device, 8 Kbytes for the PIC18F1320 device). These and other features are summarized in Table 1-1.

A block diagram of the PIC18F1220/1320 device architecture is provided in Figure 1-1. The pinouts for this device family are listed in Table 1-2.

TABLE 1-1: DEVICE FEATURES

Features	PIC18F1220	PIC18F1320
Operating Frequency	DC – 40 MHz	DC – 40 MHz
Program Memory (Bytes)	4096	8192
Program Memory (Instructions)	2048	4096
Data Memory (Bytes)	256	256
Data EEPROM Memory (Bytes)	256	256
Interrupt Sources	15	15
I/O Ports	Ports A, B	Ports A, B
Timers	4	4
Enhanced Capture/Compare/PWM Modules	1	1
Serial Communications	Enhanced USART	Enhanced USART
10-bit Analog-to-Digital Module	7 input channels	7 input channels
Resets (and Delays)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT
Programmable Low-Voltage Detect	Yes	Yes
Programmable Brown-out Reset	Yes	Yes
Instruction Set	75 Instructions	75 Instructions
Packages	18-pin SDIP 18-pin SOIC 20-pin SSOP 28-pin QFN	18-pin SDIP 18-pin SOIC 20-pin SSOP 28-pin QFN

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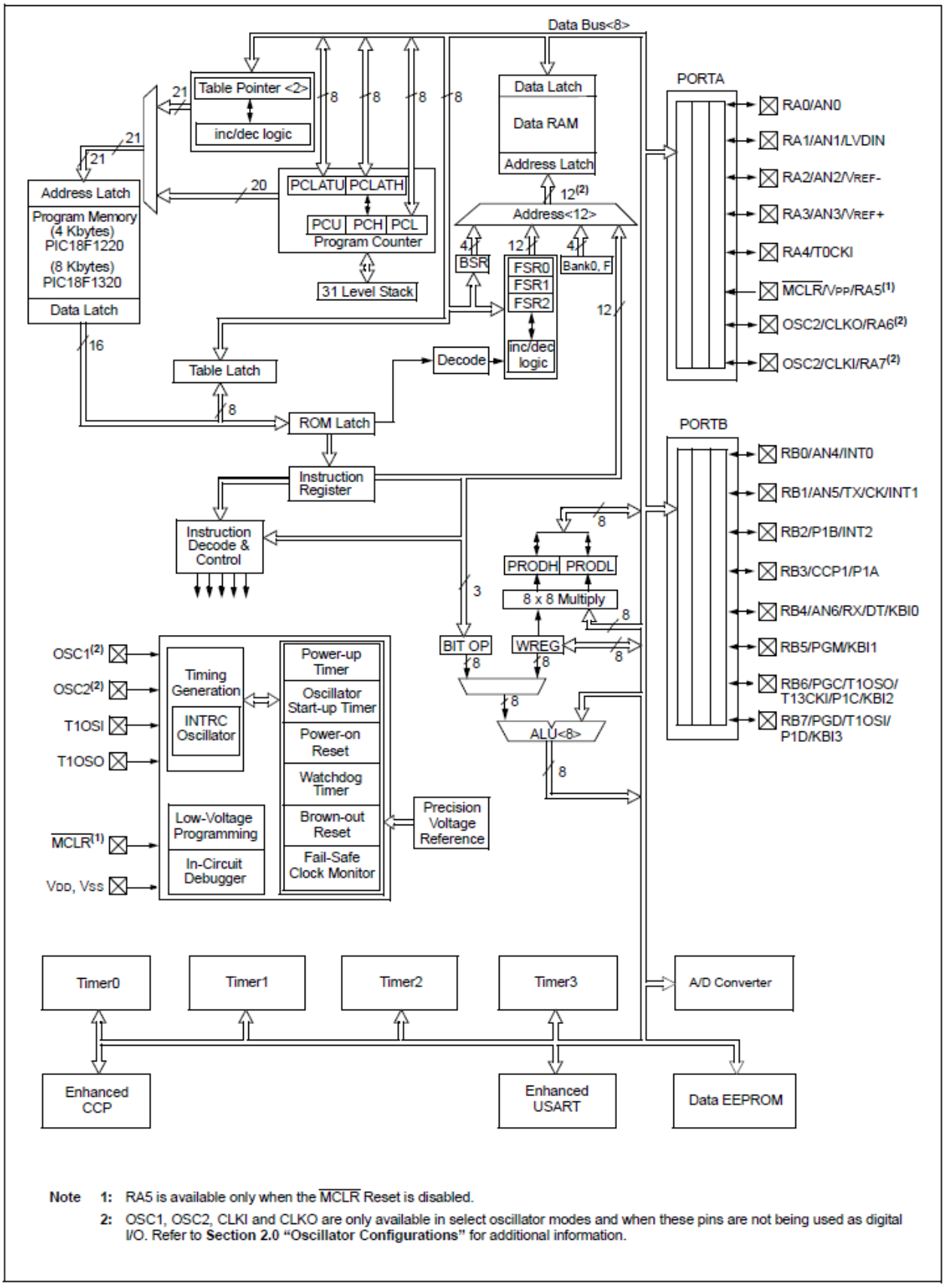
FIGURE 1-1: PIC18F1220/1320 BLOCK DIAGRAM



Note 1: RA5 is available only when the $\overline{\text{MCLR}}$ Reset is disabled.

2: OSC1, OSC2, CLKI and CLKO are only available in select oscillator modes and when these pins are not being used as digital I/O. Refer to **Section 2.0 "Oscillator Configurations"** for additional information.

TABLE 1-2: PIC18F1220/1320 PINOUT I/O DESCRIPTIONS

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP/ SOIC	SSOP	QFN			
MCLR/VPP/RA5	4	4	1			Master Clear (input) or programming voltage (input).
MCLR				I	ST	Master Clear (Reset) input. This pin is an active-low Reset to the device.
VPP				P	—	Programming voltage input.
RA5				I	ST	Digital input.
OSC1/CLKI/RA7	16	18	21			Oscillator crystal or external clock input.
OSC1				I	ST	Oscillator crystal input or external clock source input. ST buffer when configured in RC mode, CMOS otherwise.
CLKI				I	CMOS	External clock source input. Always associated with pin function OSC1. (See related OSC1/CLKI, OSC2/CLKO pins.)
RA7				I/O	ST	General purpose I/O pin.
OSC2/CLKO/RA6	15	17	20			Oscillator crystal or clock output.
OSC2				O	—	Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
CLKO				O	—	In RC, EC and INTRC modes, OSC2 pin outputs CLKO, which has 1/4 the frequency of OSC1 and denotes instruction cycle rate.
RA6				I/O	ST	General purpose I/O pin.
						PORTA is a bidirectional I/O port.
RA0/AN0	1	1	26			
RA0				I/O	ST	Digital I/O.
AN0				I	Analog	Analog input 0.
RA1/AN1/LVDIN	2	2	27			
RA1				I/O	ST	Digital I/O.
AN1				I	Analog	Analog input 1.
LVDIN				I	Analog	Low-Voltage Detect input.
RA2/AN2/VREF-	6	7	7			
RA2				I/O	ST	Digital I/O.
AN2				I	Analog	Analog input 2.
VREF-				I	Analog	A/D reference voltage (low) input.
RA3/AN3/VREF+	7	8	8			
RA3				I/O	ST	Digital I/O.
AN3				I	Analog	Analog input 3.
VREF+				I	Analog	A/D reference voltage (high) input.
RA4/T0CKI	3	3	28			
RA4				I/O	ST/OD	Digital I/O. Open-drain when configured as output.
T0CKI				I	ST	Timer0 external clock input.
RA5						See the MCLR/VPP/RA5 pin.
RA6						See the OSC2/CLKO/RA6 pin.
RA7						See the OSC1/CLKI/RA7 pin.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power; OD = Open-drain (no P diode to VDD)

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TABLE 1-2: PIC18F1220/1320 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP/ SOIC	SSOP	QFN			
						PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-ups on all inputs.
RB0/AN4/INT0	8	9	9			
RB0				I/O	TTL	Digital I/O.
AN4				I	Analog	Analog input 4.
INT0				I	ST	External interrupt 0.
RB1/AN5/TX/CK/INT1	9	10	10			
RB1				I/O	TTL	Digital I/O.
AN5				I	Analog	Analog input 5.
TX				O	—	EUSART asynchronous transmit.
CK				I/O	ST	EUSART synchronous clock (see related RX/DT).
INT1				I	ST	External interrupt 1.
RB2/P1B/INT2	17	19	23			
RB2				I/O	TTL	Digital I/O.
P1B				O	—	Enhanced CCP1/PWM output.
INT2				I	ST	External interrupt 2.
RB3/CCP1/P1A	18	20	24			
RB3				I/O	TTL	Digital I/O.
CCP1				I/O	ST	Capture 1 input/Compare 1 output/PWM 1 output.
P1A				O	—	Enhanced CCP1/PWM output.
RB4/AN6/RX/DT/KBI0	10	11	12			
RB4				I/O	TTL	Digital I/O.
AN6				I	Analog	Analog input 6.
RX				I	ST	EUSART asynchronous receive.
DT				I/O	ST	EUSART synchronous data (see related TX/CK).
KBI0				I	TTL	Interrupt-on-change pin.
RB5/PGM/KBI1	11	12	13			
RB5				I/O	TTL	Digital I/O.
PGM				I/O	ST	Low-Voltage ICSP Programming enable pin.
KBI1				I	TTL	Interrupt-on-change pin.
RB6/PGC/T1OSO/ T13CKI/P1C/KBI2	12	13	15			
RB6				I/O	TTL	Digital I/O.
PGC				I/O	ST	In-Circuit Debugger and ICSP programming clock pin.
T1OSO				O	—	Timer1 oscillator output.
T13CKI				I	ST	Timer1/Timer3 external clock output.
P1C				O	—	Enhanced CCP1/PWM output.
KBI2				I	TTL	Interrupt-on-change pin.
RB7/PGD/T1OSI/ P1D/KBI3	13	14	16			
RB7				I/O	TTL	Digital I/O.
PGD				I/O	ST	In-Circuit Debugger and ICSP programming data pin.
T1OSI				I	CMOS	Timer1 oscillator input.
P1D				O	—	Enhanced CCP1/PWM output.
KBI3				I	TTL	Interrupt-on-change pin.
VSS	5	5, 6	3, 5	P	—	Ground reference for logic and I/O pins.
VDD	14	15, 16	17, 19	P	—	Positive supply for logic and I/O pins.
NC	—	—	18	—	—	No connect.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power; OD = Open-drain (no P diode to VDD)

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XBee™/XBee-PRO™ OEM RF Modules

XBee/XBee-PRO OEM RF Modules
RF Module Operation
RF Module Configuration
Appendices

Product Manual v1.xAx - 802.15.4 Protocol
For OEM RF Module Part Numbers: XB24-...-001, XBP24-...-001

IEEE® 802.15.4 OEM RF Modules by MaxStream

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M100232
2007.05.031

1. XBee/XBee-PRO OEM RF Modules

The XBee and XBee-PRO OEM RF Modules were engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of data between devices.

The modules operate within the ISM 2.4 GHz frequency band and are pin-for-pin compatible with each other.

1.1. Key Features

Long Range Data Integrity

XBee

- Indoor/Urban: up to 100' (30 m)
- Outdoor line-of-sight: up to 300' (100 m)
- Transmit Power: 1 mW (0 dBm)
- Receiver Sensitivity: -92 dBm

XBee-PRO

- Indoor/Urban: up to 300' (100 m)
- Outdoor line-of-sight: up to 1 mile (1500 m)
- Transmit Power: 100 mW (20 dBm) EIRP
- Receiver Sensitivity: -100 dBm

RF Data Rate: 250,000 bps

Low Power

XBee

- TX Current: 45 mA (@3.3 V)
- RX Current: 50 mA (@3.3 V)
- Power-down Current: < 10 µA

XBee-PRO

- TX Current: 215 mA (@3.3 V)
- RX Current: 55 mA (@3.3 V)
- Power-down Current: < 10 µA

ADC and I/O line support

Analog-to-digital conversion, Digital I/O

I/O Line Passing

Advanced Networking & Security

Retries and Acknowledgements

DSSS (Direct Sequence Spread Spectrum)

Each direct sequence channels has over 65,000 unique network addresses available

Source/Destination Addressing

Unicast & Broadcast Communications

Point-to-point, point-to-multipoint and peer-to-peer topologies supported

Coordinator/End Device operations

Easy-to-Use

No configuration necessary for out-of box RF communications

Free X-CTU Software (Testing and configuration software)

AT and API Command Modes for configuring module parameters

Extensive command set

Small form factor

Free & Unlimited RF-XPert Support

1.1.1. Worldwide Acceptance

FCC Approval (USA) Refer to Appendix A [p59] for FCC Requirements. Systems that contain XBee/XBee-PRO RF Modules inherit MaxStream Certifications.

ISM (Industrial, Scientific & Medical) **2.4 GHz frequency band**

Manufactured under **ISO 9001:2000** registered standards

XBee/XBee-PRO RF Modules are optimized for use in the **United States, Canada, Australia, Israel and Europe**. Contact MaxStream for complete list of government agency approvals.

1.2. Specifications

Table 1-01. Specifications of the XBee/XBee-PRO OEM RF Modules

Specification	XBee	XBee-PRO
Performance		
Indoor/Urban Range	up to 100 ft. (30 m)	Up to 300' (100 m)
Outdoor RF line-of-sight Range	up to 300 ft. (100 m)	Up to 1 mile (1500 m)
Transmit Power Output (software selectable)	1mW (0 dBm)	60 mW (18 dBm) conducted, 100 mW (20 dBm) EIRP*
RF Data Rate	250,000 bps	250,000 bps
Serial Interface Data Rate (software selectable)	1200 - 115200 bps (non-standard baud rates also supported)	1200 - 115200 bps (non-standard baud rates also supported)
Receiver Sensitivity	-92 dBm (1% packet error rate)	-100 dBm (1% packet error rate)
Power Requirements		
Supply Voltage	2.8 – 3.4 V	2.8 – 3.4 V
Transmit Current (typical)	45mA (@ 3.3 V)	If PL=0 (10dBm): 137mA(@3.3V), 139mA(@3.0V) PL=1 (12dBm): 155mA (@3.3V), 153mA(@3.0V) PL=2 (14dBm): 170mA (@3.3V), 171mA(@3.0V) PL=3 (16dBm): 188mA (@3.3V), 195mA(@3.0V) PL=4 (18dBm): 215mA (@3.3V), 227mA(@3.0V)
Idle / Receive Current (typical)	50mA (@ 3.3 V)	55mA (@ 3.3 V)
Power-down Current	< 10 µA	< 10 µA
General		
Operating Frequency	ISM 2.4 GHz	ISM 2.4 GHz
Dimensions	0.960" x 1.087" (2.438cm x 2.761cm)	0.960" x 1.297" (2.438cm x 3.294cm)
Operating Temperature	-40 to 85° C (industrial)	-40 to 85° C (industrial)
Antenna Options	Integrated Whip, Chip or U.FL Connector	Integrated Whip, Chip or U.FL Connector
Networking & Security		
Supported Network Topologies	Point-to-point, Point-to-multipoint & Peer-to-peer	
Number of Channels (software selectable)	16 Direct Sequence Channels	12 Direct Sequence Channels
Addressing Options	PAN ID, Channel and Addresses	PAN ID, Channel and Addresses
Agency Approvals		
United States (FCC Part 15.247)	OUR-XBEE	OUR-XBEEPRO
Industry Canada (IC)	4214A XBEE	4214A XBEEPRO
Europe (CE)	ETSI	ETSI (Max. 10 dBm transmit power output)*
Japan	n/a	005NYCA0378 (Max. 10 dBm transmit power output)**

* When operating in Europe: XBee-PRO RF Modules must be configured to operate at a maximum transmit power output level of 10 dBm. The power output level is set using the PL command. The PL parameter must equal "0" (10 dBm).

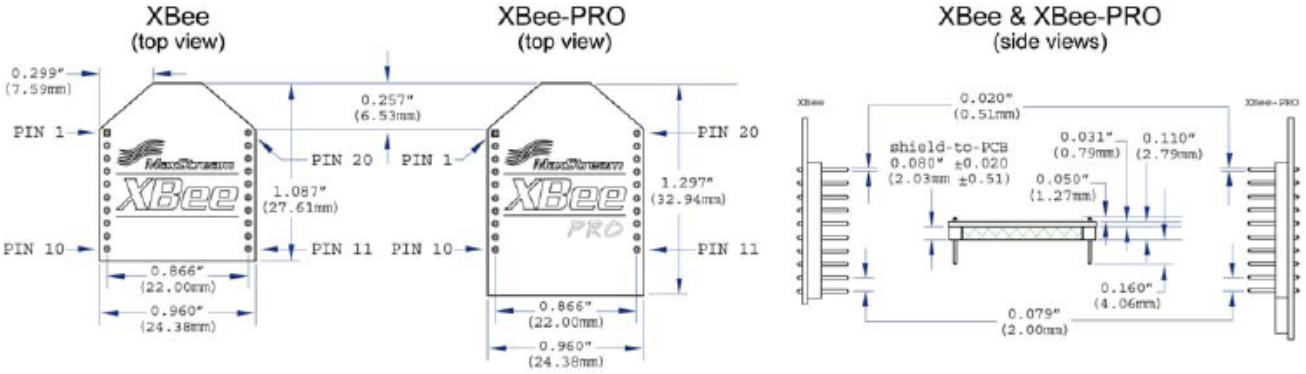
Additionally, European regulations stipulate an EIRP power maximum of 12.86 dBm (19 mW) for the XBee-PRO and 12.11 dBm for the XBee when integrating high-gain antennas.

** When operating in Japan: Transmit power output is limited to 10 dBm. A special part number is required when ordering modules approved for use in Japan. Contact MaxStream for more information [call 1-801-765-9885 or send e-mails to sales@maxstream.net].

Antenna Options: The ranges specified are typical when using the integrated Whip (1.5 dBi) and Dipole (2.1 dBi) antennas. The Chip antenna option provides advantages in its form factor; however, it typically yields shorter range than the Whip and Dipole antenna options when transmitting outdoors. For more information, refer to the "XBee Antenna" application note located on MaxStream's web site (http://www.maxstream.net/support/knowledgebase/article.php?kb=153).

1.3. Mechanical Drawings

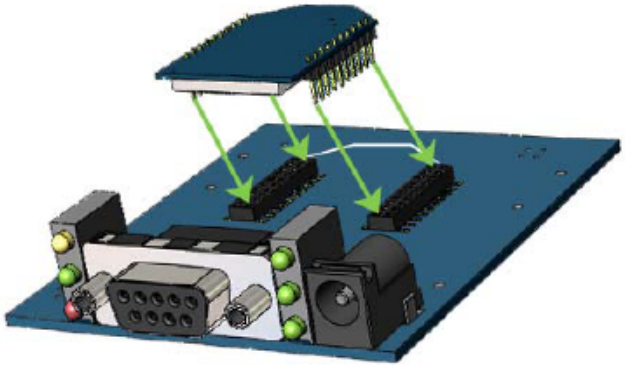
Figure 1-01. Mechanical drawings of the XBee/XBee-PRO OEM RF Modules (antenna options not shown)
The XBee and XBee-PRO RF Modules are pin-for-pin compatible.



1.4. Mounting Considerations

The XBee/XBee-PRO RF Module was designed to mount into a receptacle (socket) and therefore does not require any soldering when mounting it to a board. The XBee Development Kits contain RS-232 and USB interface boards which use two 20-pin receptacles to receive modules.

Figure 1-02. XBee Module Mounting to an RS-232 Interface Board.



The receptacles used on MaxStream development boards are manufactured by Century Interconnect. Several other manufacturers provide comparable mounting solutions; however, MaxStream currently uses the following receptacles:

- Through-hole single-row receptacles -
  Samtec P/N: MMS-110-01-L-SV (or equivalent)
- Surface-mount double-row receptacles -
  Century Interconnect P/N: CPRMSL20-D-0-1 (or equivalent)
- Surface-mount single-row receptacles -
  Samtec P/N: SMM-110-02-SM-S

MaxStream also recommends printing an outline of the module on the board to indicate the orientation the module should be mounted.

1.5. Pin Signals

Figure 1-03. XBee/XBee-PRO RF Module Pin Numbers
(top sides shown - shields on bottom)

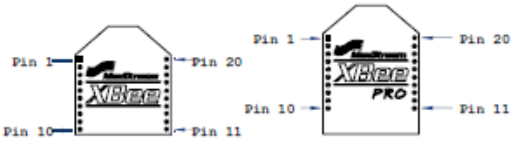


Table 1-02. Pin Assignments for the XBee and XBee-PRO Modules
(Low-asserted signals are distinguished with a horizontal line above signal name.)

Pin #	Name	Direction	Description
1	VCC	-	Power supply
2	DOUT	Output	UART Data Out
3	DIN / **CONFIG**	Input	UART Data In
4	DO8*	Output	Digital Output 8
5	**RESET**	Input	Module Reset (reset pulse must be at least 200 ns)
6	PWM0 / RSSI	Output	PWM Output 0 / RX Signal Strength Indicator
7	PWM1	Output	PWM Output 1
8	[reserved]	-	Do not connect
9	DTR / SLEEP_RQ / DI8	Input	Pin Sleep Control Line or Digital Input 8
10	GND	-	Ground
11	AD4 / DIO4	Either	Analog Input 4 or Digital I/O 4
12	**CTS** / DIO7	Either	Clear-to-Send Flow Control or Digital I/O 7
13	ON / **SLEEP**	Output	Module Status Indicator
14	VREF	Input	Voltage Reference for A/D Inputs
15	Associate / AD5 / DIO5	Either	Associated Indicator, Analog Input 5 or Digital I/O 5
16	**RTS** / AD6 / DIO6	Either	Request-to-Send Flow Control, Analog Input 6 or Digital I/O 6
17	AD3 / DIO3	Either	Analog Input 3 or Digital I/O 3
18	AD2 / DIO2	Either	Analog Input 2 or Digital I/O 2
19	AD1 / DIO1	Either	Analog Input 1 or Digital I/O 1
20	AD0 / DIO0	Either	Analog Input 0 or Digital I/O 0

* Function is not supported at the time of this release

Design Notes:

- Minimum connections: VCC, GND, DOUT & DIN
- Minimum connections for updating firmware: VCC, GND, DIN, DOUT, RTS & DTR
- Signal Direction is specified with respect to the module
- Module includes a 50k Ω pull-up resistor attached to **RESET**
- Several of the input pull-ups can be configured using the PR command
- Unused pins should be left disconnected

1.6. Electrical Characteristics

Table 1-03. DC Characteristics (VCC = 2.8 - 3.4 VDC)

Symbol	Characteristic	Condition	Min	Typical	Max	Unit
V_{IL}	Input Low Voltage	All Digital Inputs	-	-	0.35 * VCC	V
V_{IH}	Input High Voltage	All Digital Inputs	0.7 * VCC	-	-	V
V_{OL}	Output Low Voltage	I_{OL} = 2 mA, VCC >= 2.7 V	-	-	0.5	V
V_{OH}	Output High Voltage	I_{OH} = -2 mA, VCC >= 2.7 V	VCC - 0.5	-	-	V
II_{IN}	Input Leakage Current	V_{IN} = VCC or GND, all inputs, per pin	-	0.025	1	µA
II_{OZ}	High Impedance Leakage Current	V_{IN} = VCC or GND, all I/O High-Z, per pin	-	0.025	1	µA
TX	Transmit Current	VCC = 3.3 V	-	45 (XBee) / 215 (PRO)	-	mA
RX	Receive Current	VCC = 3.3 V	-	50 (XBee) / 55 (PRO)	-	mA
PWR-DWN	Power-down Current	SM parameter = 1	-	< 10	-	µA

Table 1-04. ADC Characteristics (Operating)

Symbol	Characteristic	Condition	Min	Typical	Max	Unit
V_{REFH}	VREF - Analog-to-Digital converter reference range		2.08	-	V_{DDAD}	V
I_{REF}	VREF - Reference Supply Current	Enabled	-	200	-	µA
		Disabled or Sleep Mode	-	< 0.01	0.02	µA
V_{INDC}	Analog Input Voltage[1]		V_{SSAD} - 0.3	-	V_{DDAD} + 0.3	V

1. Maximum electrical operating range, not valid conversion range.

Table 1-05. ADC Timing/Performance Characteristics[1]

Symbol	Characteristic	Condition	Min	Typical	Max	Unit
R_{AS}	Source Impedance at Input[2]		-	-	10	kΩ
V_{AIN}	Analog Input Voltage[3]		V_{REFL}		V_{REFH}	V
RES	Ideal Resolution (1 LSB)[4]	$2.08V \le V_{DDAD} \le 3.6V$	2.031	-	3.516	mV
DNL	Differential Non-linearity[5]		-	±0.5	±1.0	LSB
INL	Integral Non-linearity[6]		-	±0.5	±1.0	LSB
E_{ZS}	Zero-scale Error[7]		-	±0.4	±1.0	LSB
F_{FS}	Full-scale Error[8]		-	±0.4	±1.0	LSB
E_{IL}	Input Leakage Error[9]		-	±0.05	±5.0	LSB
E_{TU}	Total Unadjusted Error[10]		-	±1.1	±2.5	LSB

1. All ACCURACY numbers are based on processor and system being in WAIT state (very little activity and no IO switching) and that adequate low-pass filtering is present on analog input pins (filter with 0.01 µF to 0.1 µF capacitor between analog input and VREFL). Failure to observe these guidelines may result in system or microcontroller noise causing accuracy errors which will vary based on board layout and the type and magnitude of the activity.
Data transmission and reception during data conversion may cause some degradation of these specifications, depending on the number and timing of packets. It is advisable to test the ADCs in your installation if best accuracy is required.
2. R_{AS} is the real portion of the impedance of the network driving the analog input pin. Values greater than this amount may not fully charge the input circuitry of the ATD resulting in accuracy error.
3. Analog input must be between V_{REFL} and V_{REFH} for valid conversion. Values greater than V_{REFH} will convert to $3FF.
4. The resolution is the ideal step size or 1LSB = $(V_{REFH}-V_{REFL})/1024$
5. Differential non-linearity is the difference between the current code width and the ideal code width (1LSB). The current code width is the difference in the transition voltages to and from the current code.
6. Integral non-linearity is the difference between the transition voltage to the current code and the adjusted ideal transition voltage for the current code. The adjusted ideal transition voltage is $(Current\ Code-1/2)*(1/((V_{REFH}+E_{FS})-(V_{REFL}+E_{ZS})))$.
7. Zero-scale error is the difference between the transition to the first valid code and the ideal transition to that code. The Ideal transition voltage to a given code is $(Code-1/2)*(1/(V_{REFH}-V_{REFL}))$.
8. Full-scale error is the difference between the transition to the last valid code and the ideal transition to that code. The ideal transition voltage to a given code is $(Code-1/2)*(1/(V_{REFH}-V_{REFL}))$.
9. Input leakage error is error due to input leakage across the real portion of the impedance of the network driving the analog pin. Reducing the impedance of the network reduces this error.
10. Total unadjusted error is the difference between the transition voltage to the current code and the ideal straight-line transfer function. This measure of error includes inherent quantization error (1/2LSB) and circuit error (differential, integral, zero-scale, and full-scale) error. The specified value of E_{TU} assumes zero E_{IL} (no leakage or zero real source impedance).

2. RF Module Operation

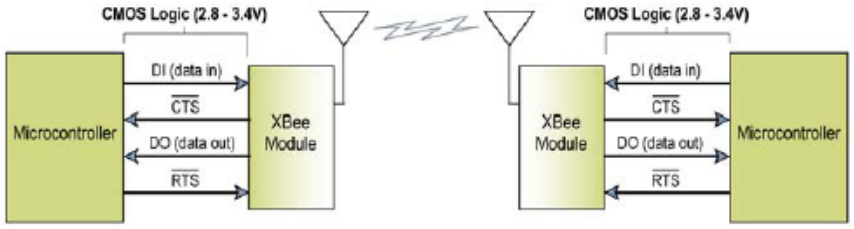
2.1. Serial Communications

The XBee/XBee-PRO OEM RF Modules interface to a host device through a logic-level asynchronous serial port. Through its serial port, the module can communicate with any logic and voltage compatible UART; or through a level translator to any serial device (For example: Through a MaxStream proprietary RS-232 or USB interface board).

2.1.1. UART Data Flow

Devices that have a UART interface can connect directly to the pins of the RF module as shown in the figure below.

Figure 2-01. System Data Flow Diagram in a UART-interfaced environment
(Low-asserted signals distinguished with horizontal line over signal name.)

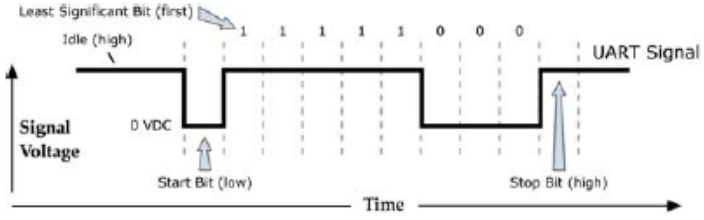


Serial Data

Data enters the module UART through the DI pin (pin 3) as an asynchronous serial signal. The signal should idle high when no data is being transmitted.

Each data byte consists of a start bit (low), 8 data bits (least significant bit first) and a stop bit (high). The following figure illustrates the serial bit pattern of data passing through the module.

Figure 2-02. UART data packet 0x1F (decimal number "31") as transmitted through the RF module
Example Data Format is 8-N-1 (bits - parity - # of stop bits)



The module UART performs tasks, such as timing and parity checking, that are needed for data communications. Serial communications depend on the two UARTs to be configured with compatible settings (baud rate, parity, start bits, stop bits, data bits).

2.1.2. Transparent Operation

By default, XBee/XBee-PRO RF Modules operate in Transparent Mode. When operating in this mode, the modules act as a serial line replacement - all UART data received through the DI pin is queued up for RF transmission. When RF data is received, the data is sent out the DO pin.

Serial-to-RF Packetization

Data is buffered in the DI buffer until one of the following causes the data to be packetized and transmitted:

1. No serial characters are received for the amount of time determined by the RO (Packetization Timeout) parameter. If RO = 0, packetization begins when a character is received.
2. The maximum number of characters that will fit in an RF packet (100) is received.
3. The Command Mode Sequence (GT + CC + GT) is received. Any character buffered in the DI buffer before the sequence is transmitted.

If the module cannot immediately transmit (for instance, if it is already receiving RF data), the serial data is stored in the DI Buffer. The data is packetized and sent at any RO timeout or when 100 bytes (maximum packet size) are received.

If the DI buffer becomes full, hardware or software flow control must be implemented in order to prevent overflow (loss of data between the host and module).

2.1.3. API Operation

API (Application Programming Interface) Operation is an alternative to the default Transparent Operation. The frame-based API extends the level to which a host application can interact with the networking capabilities of the module.

When in API mode, all data entering and leaving the module is contained in frames that define operations or events within the module.

Transmit Data Frames (received through the DI pin (pin 3)) include:

- RF Transmit Data Frame
- Command Frame (equivalent to AT commands)

Receive Data Frames (sent out the DO pin (pin 2)) include:

- RF-received data frame
- Command response
- Event notifications such as reset, associate, disassociate, etc.

The API provides alternative means of configuring modules and routing data at the host application layer. A host application can send data frames to the module that contain address and payload information instead of using command mode to modify addresses. The module will send data frames to the application containing status packets; as well as source, RSSI and payload information from received data packets.

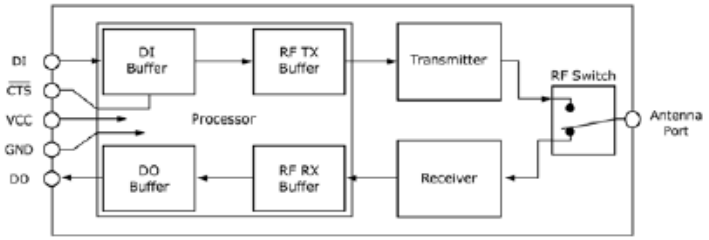
The API operation option facilitates many operations such as the examples cited below:

-> Transmitting data to multiple destinations without entering Command Mode
-> Receive success/failure status of each transmitted RF packet
-> Identify the source address of each received packet

To implement API operations, refer to API sections [p54].

2.1.4. Flow Control

Figure 2-03. Internal Data Flow Diagram



DI (Data In) Buffer

When serial data enters the RF module through the DI pin (pin 3), the data is stored in the DI Buffer until it can be processed.

Hardware Flow Control ($\overline{\text{CTS}}$). When the DI buffer is 17 bytes away from being full; by default, the module de-asserts $\overline{\text{CTS}}$ (high) to signal to the host device to stop sending data [refer to D7 (DIO7 Configuration) parameter]. $\overline{\text{CTS}}$ is re-asserted after the DI Buffer has 34 bytes of memory available.

How to eliminate the need for flow control:

1. Send messages that are smaller than the DI buffer size.
2. Interface at a lower baud rate [BD (Interface Data Rate) parameter] than the throughput data rate.

Case in which the DI Buffer may become full and possibly overflow:

If the module is receiving a continuous stream of RF data, any serial data that arrives on the DI pin is placed in the DI Buffer. The data in the DI buffer will be transmitted over-the-air when the module is no longer receiving RF data in the network.

Refer to the RO (Packetization Timeout), BD (Interface Data Rate) and D7 (DIO7 Configuration) command descriptions for more information.

DO (Data Out) Buffer

When RF data is received, the data enters the DO buffer and is sent out the serial port to a host device. Once the DO Buffer reaches capacity, any additional incoming RF data is lost.

Hardware Flow Control ($\overline{\text{RTS}}$). If $\overline{\text{RTS}}$ is enabled for flow control (D6 (DIO6 Configuration) Parameter = 1), data will not be sent out the DO Buffer as long as $\overline{\text{RTS}}$ (pin 16) is de-asserted.

Two cases in which the DO Buffer may become full and possibly overflow:

1. If the RF data rate is set higher than the interface data rate of the module, the module will receive data from the transmitting module faster than it can send the data to the host.
2. If the host does not allow the module to transmit data out from the DO buffer because of being held off by hardware or software flow control.

Refer to the D6 (DIO6 Configuration) command description for more information.

2.2. ADC and Digital I/O Line Support

The XBee/XBee-PRO RF Modules support ADC (Analog-to-digital conversion) and digital I/O line passing. The following pins support multiple functions:

Table 2-01. Pin functions and their associated pin numbers and commands
AD = Analog-to-Digital Converter, DIO = Digital Input/Output
Pin functions not applicable to this section are denoted within (parenthesis).

Pin Function	Pin#	AT Command
AD0 / DIO0	20	D0
AD1 / DIO1	19	D1
AD2 / DIO2	18	D2
AD3 / DIO3 / (COORD_SEL)	17	D3
AD4 / DIO4	11	D4
AD5 / DIO5 / (ASSOCIATE)	15	D5
DIO6 / (RTS)	16	D6
DIO7 / (CTS)	12	D7
DI8 / (DTR) / (Sleep_RQ)	9	D8

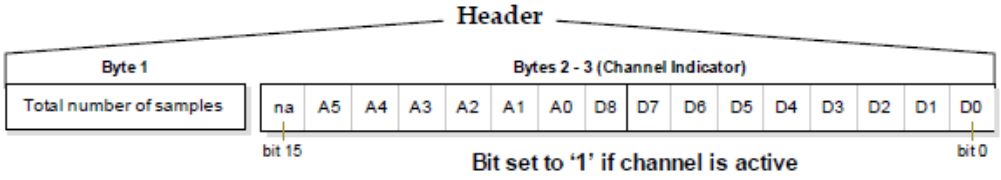
To enable ADC and DIO pin functions:

For ADC Support:	Set ATDn = 2
For Digital Input support:	Set ATDn = 3
For Digital Output Low support:	Set ATDn = 4
For Digital Output High support:	Set ATDn = 5

2.2.1. I/O Data Format

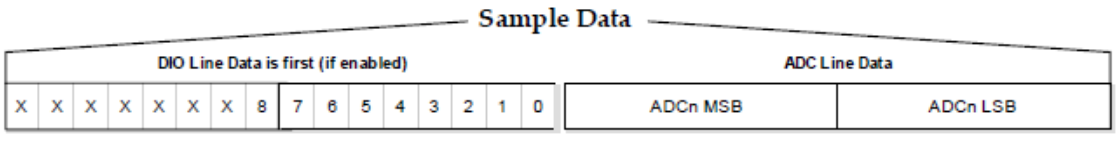
I/O data begins with a header. The first byte of the header defines the number of samples forthcoming. A sample is comprised of input data and the inputs can contain either DIO or ADC. The last 2 bytes of the header (Channel Indicator) define which inputs are active. Each bit represents either a DIO line or ADC channel.

Figure 2-04. Header


Header
Byte 1
Bytes 2 - 3 (Channel Indicator)
Total number of samples
na A5 A4 A3 A2 A1 A0 D8 D7 D6 D5 D4 D3 D2 D1 D0
bit 15
bit 0
Bit set to '1' if channel is active

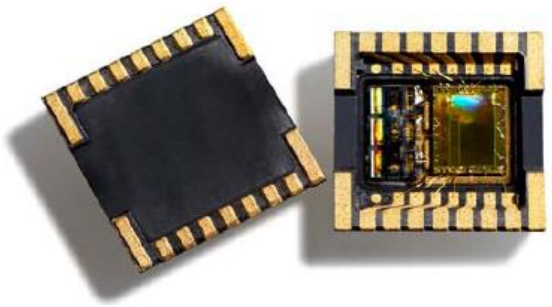
Sample data follows the header and the channel indicator frame is used to determine how to read the sample data. If any of the DIO lines are enabled, the first 2 bytes are the DIO data and the ADC data follows. ADC channel data is stored as an unsigned 10-bit value right-justified on a 16-bit boundary.

Figure 2-05. Sample Data



VTI TECHNOLOGIES

SCA3000 Assembly Instructions



SCA3000 Series
3-axis accelerometer

1 Objective

This document describes guidelines for Printed Wiring Board (PWB) design and assembly of the SCA3000 Component. It aims to help customers achieve the optimum soldering process.
It should be emphasized that this document serves only as a design guideline to help develop the optimal assembly conditions. It is essential that users also use their own manufacturing practices and experience to be able to fulfill the needs of varying end-use applications.

2 VTI's Molded Interconnection Device Package (MID)

The housing of the SCA3000 component is relatively new packaging concept, which is called a molded interconnection device (MID), which is a modified Dual Flat-pack No-lead package (DFN). The MID housing is leadless component as well as DFN package. The SCA3000 component is a surface mount plastic package with leads located at the bottom of the package, see picture 1.

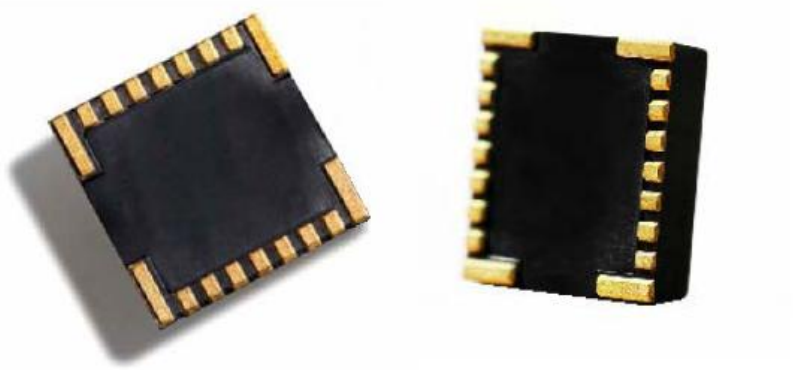


Figure 1. 3D pictures of the SCA3000 component. The SCA3000 component leads are located at the bottom of the package.

MID-technology offers a variety of benefits including reduced lead inductance, a small sized "near chip scale" footprint, thin profile, and low weight. The MID component is an injection molded plastic substrate, and the conductive circuit pattern is manufactured on its surface. The SCA3000 component housing is manufactured by the LDS (Laser Direct Structuring) MID-process. The process flow of LDS - MID package is presented in figure 2.

1. Molding of package

2. Laser structuring of areas to be metallized

3. Cu-plating of lasered areas

4. Final plating over copper

Figure 2. Manufacturing process for the LDS – Molded Interconnect Device.

The solder pads of a MID package are rougher than the pads of traditional lead frame packages. A photo of a MID package solder pad is presented in figure 3. The rougher surface of the solder pad can produce more voids in the solder joints, which is also observed in guidelines of this technical note.

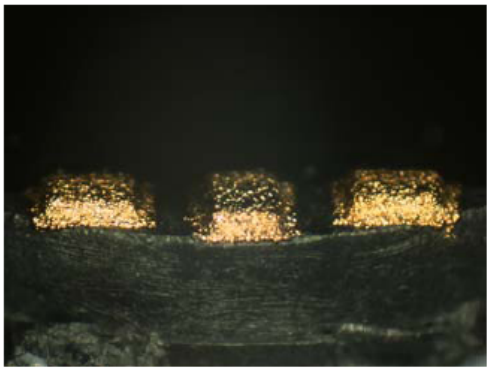


Figure 3. Photo of a MID solder pad. Surface is rougher than with traditional SMD components.

Because the MID platform represents the latest in surface mount packaging technology, it is important that the design of the printed wiring board, as well as the assembly process, follows the suggested guidelines outlined in this document.

3 SCA3000 Package Outline and Dimensions

The outline and dimensions for the SCA3000 MID package are presented in figure 4.

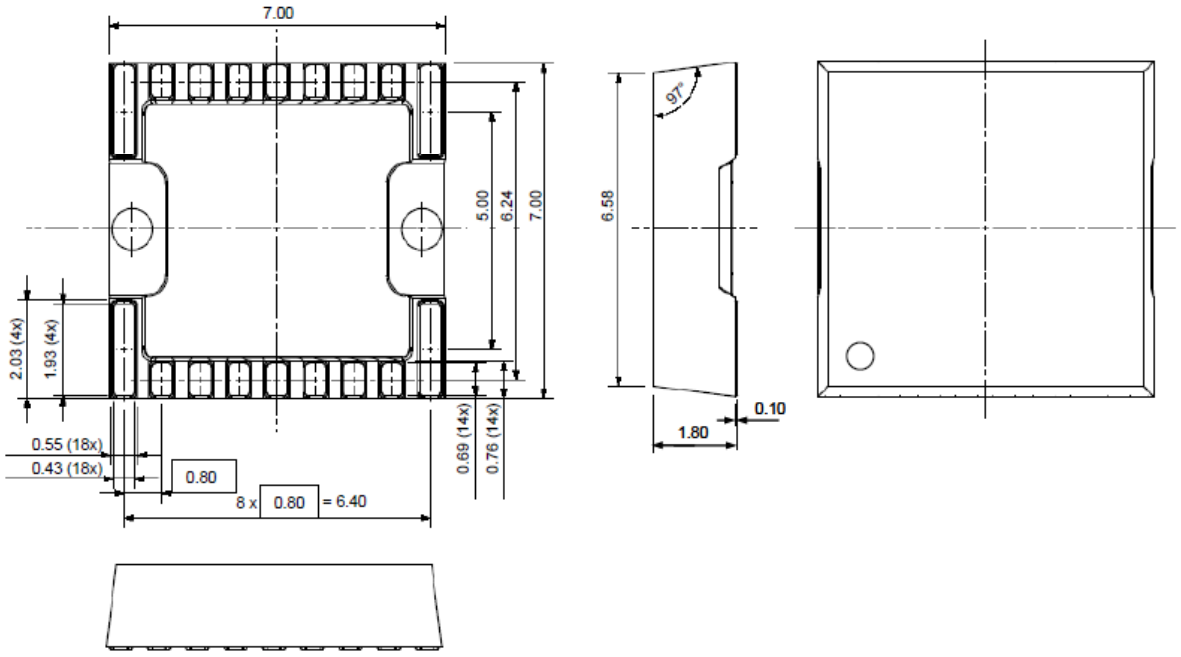


Figure 4. Outline and dimensions of the SCA3000 component.

4 Tape and reel specifications

Packing tape dimensions, unreeling direction and SCA3000 component orientation are presented in figure 5, table 1 and table 2 below (dimensions are in millimeters [mm]).

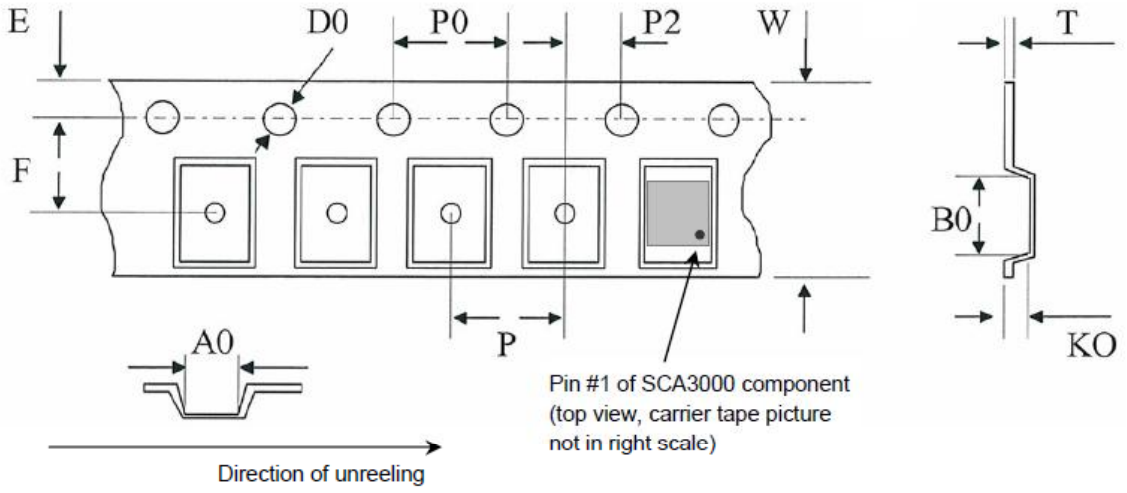


Figure 5. SCA3000 packing tape and component orientation on tape.

Table 1. SCA3000 packing tape pocket dimensions [mm].

A0	B0	KO
7.2 ±0.1	7.4 ±0.1	1.9 ±0.1

Table 2. Dimensions for SCA3000 packing tape [mm].

Parameter	Min	Nominal	Max
F	11.40	11.50	11.60
E	1.65	1.75	1.85
W	23.90	24.00	24.30
P2	1.90	2.00	2.10
P0	3.90	4.00	4.10
10P0	39.80	40.00	40.20
D0	1.50	1.50	1.60
D1	1.50	1.50	1.75
T	0.272	0.292	0.312
P	11.90	12.00	12.10

APPENDIX E

PCB Design